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Work Plan for a Treatability Study to Evaluate Intrinsic Remediation of Groundwater at Site FT-1

Fairchild Air Force Base
Spokane, Washington

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

and

92 CES/CEVR
Fairchild Air Force Base
Spokane, Washington

October 1995

PARSONS
ENGINEERING SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado 80290

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WORK PLAN FOR A TREATABILITY STUDY TO EVALUATE THE INTRINSIC REMEDIATION OF GROUNDWATER AT SITE FT-1 FAIRCHILD AIR FORCE BASE, WASHINGTON

Prepared for

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

and

92 CES/CEVR
FAIRCHILD AIR FORCE BASE
SPOKANE, WASHINGTON

October 1995

Prepared by

Parsons Engineering Science, Inc.
1700 Broadway Suite 900
Denver, Colorado 80290

022/722425/FCWP/9.WW6

AQM01-01-0311

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SECTION 1

INTRODUCTION

This work plan was prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering Science, Inc. (ES), and presents the scope of work required for the collection of data necessary to conduct a treatability study (TS) for the intrinsic remediation of groundwater contaminated with petroleum hydrocarbons and chlorinated aliphatic hydrocarbons (CAHs) at the Priority-One Site Fire Training Area 01 (FT-1) located at Fairchild Air Force Base (AFB), 12 miles west of Spokane, Washington (the Base). The record-of-decision (ROD) for FT-1 specifies the use of air sparging to remediate volatile organic compounds (VOCs) in site groundwater. Therefore, this TS will assess naturally occurring contaminant attenuation processes for groundwater and evaluate how these processes will operate in conjunction with the future air sparging system. This work plan is oriented toward the collection of hydrogeologic data to be used as input into groundwater flow and solute transport models to evaluate intrinsic remediation for restoration of groundwater contaminated with benzene, toluene, ethylbenzene, xylenes (BTEX), and CAHs.

As used in this report, the term "intrinsic remediation" refers to a management strategy that relies on natural attenuation mechanisms to remediate contaminants dissolved in groundwater and to control the potential for receptor exposure to site-related contaminants in the subsurface. "Natural attenuation" refers to the actual physical, chemical, and biological processes that facilitate intrinsic remediation. Mechanisms for natural attenuation of BTEX and CAHs include advection, dispersion, dilution from recharge, sorption, volatilization, and biodegradation. Of these processes, biodegradation is the only mechanism working to transform contaminants into innocuous byproducts. Intrinsic bioremediation occurs when indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without the addition of nutrients. Patterns and rates of intrinsic remediation can vary markedly from site to site depending on governing physical and chemical processes.

As part of the TS, the contaminant fate and transport modeling effort will have two primary objectives: 1) predict the future extent and concentration of dissolved contaminant plumes by modeling the effects of advection, dispersion, sorption, and biodegradation in conjunction with an air sparging system; and 2) assess the possible exposure of potential downgradient receptors to contaminant concentrations that exceed levels intended to be protective of human health and the environment. The modeling efforts for the FT-1 site at Fairchild AFB will involve completion of several tasks, which are described in the following sections.

This work plan was developed following discussions among representatives from the Air Force Center for Environmental Excellence (AFCEE), the 92nd Civil Engineering Squadron--Environmental (92 CES/CEVR), and Parsons ES at a meeting held at the Base on July 11, 1995, to discuss the statement of work (SOW) for this project, and on a review of existing site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993), and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and 92 CES/CEVR.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide a TS for intrinsic remediation of groundwater contamination at FT-1 in conjunction with the ROD-specified air sparging system. However, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with the US Environmental Protection Agency (USEPA) and Parsons ES to document the biodegradation and resulting attenuation of fuel hydrocarbons and solvents dissolved in groundwater, and to model this degradation using numerical and analytical groundwater model codes. For this reason, the work described in this work plan is directed toward the collection of data in support of this initiative. This work plan describes the site characterization activities to be performed by personnel from Parsons ES and the USEPA National Risk Management Research Laboratory (NRMRL) Subsurface Protection and Remediation Division, formerly the USEPA Robert S. Kerr Environmental Research Laboratory, in support of the TS and the groundwater modeling effort. Field activities will be performed to determine if mobile and residual light nonaqueous-phase liquid (LNAPL) exists at the site and to determine the extent of LNAPL and dissolved contamination. The data collected during the TS will be used along with data from previous investigations to supplement the characterization of contamination at the site, and as input for the groundwater flow and solute transport models to make predictions of the future concentrations and extent of contamination.

Site characterization activities in support of the TS will include: 1) determination of preferential contaminant migration and potential receptor exposure pathways; 2) soil sampling using the Geoprobe® direct-push technology; 3) groundwater monitoring point placement; 4) groundwater sampling; and 5) aquifer testing. The materials and methodologies to accomplish these activities are described herein. Previously reported site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the groundwater flow and solute transport models. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site will be obtained from widely accepted published literature and used for model input. Sensitivity analyses will be conducted for the parameters that are known to have the greatest influence on the model results, and where possible, the model will be calibrated using historical site data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of available previously reported, site-specific data and a preliminary conceptual hydrogeologic model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the TS report format. Section 5 describes

the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There are two appendices to this work plan. Appendix A contains a listing of containers, preservatives, packaging, and shipping requirements for soil and groundwater samples. Appendix B contains summary site data, including available well logs and summaries of historical soil and groundwater analytical data from previous field investigation work.

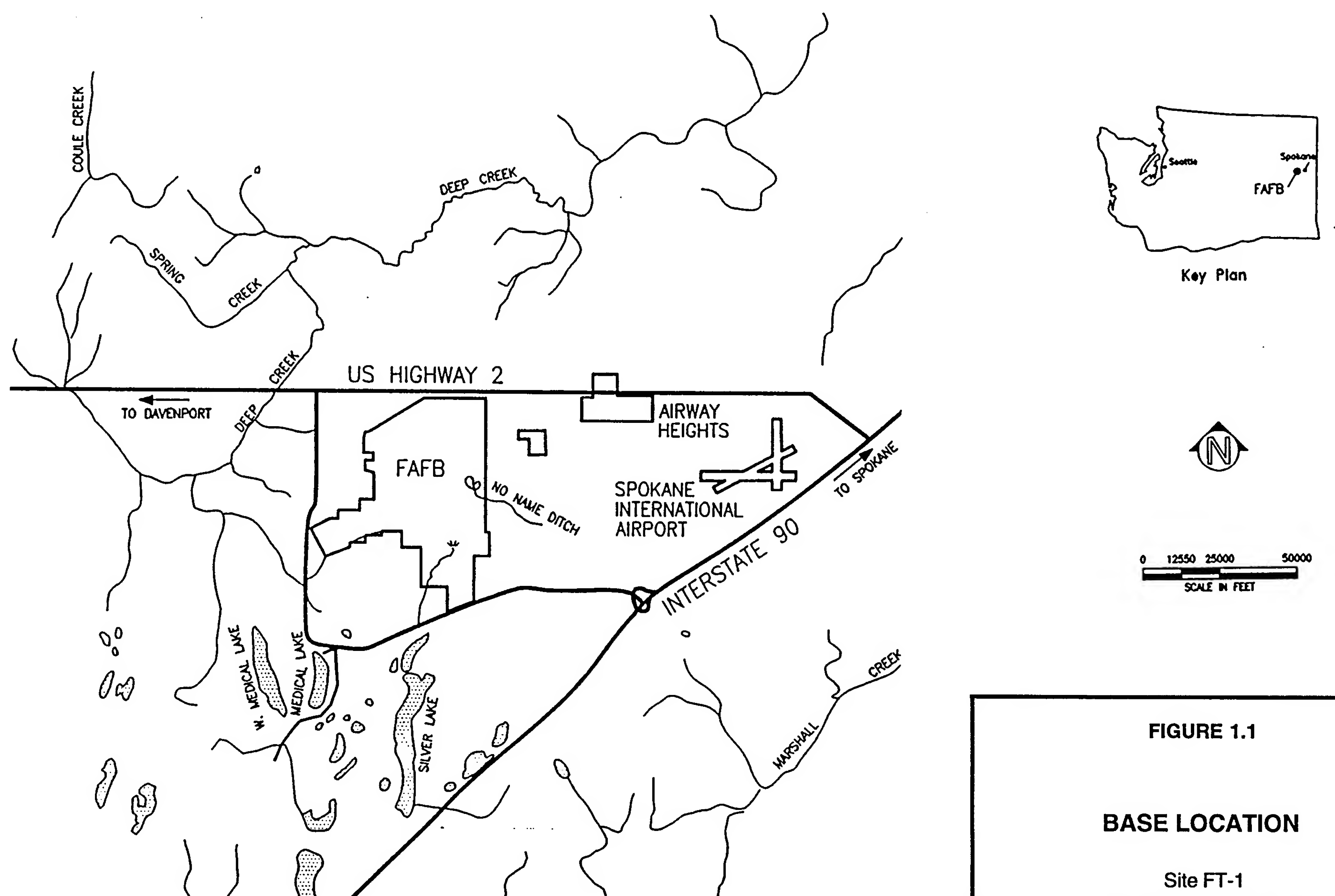
1.2 BACKGROUND

Fairchild AFB occupies an area of approximately 4,300 acres 12 miles west of Spokane, Washington (Figure 1.1). The Base is divided roughly in half by the main northeast/southwest runway (Figure 1.2). Aircraft operational facilities, approximately 1,600 Base housing units, an elementary school, a hospital, and support facilities for the tenants housed on-Base lie north of the runway. The air traffic control tower, weapons storage area, and survival training school lie to the south of the runway [Halliburton NUS (HNUS), 1993a].

The Base was established in 1942 as an Army repair depot and transferred to the Strategic Air Command (SAC) in 1947. In 1992, Base control was transferred to the Air Combat Command (ACC). Currently, the Base is operated by the Air Mobility Command (AMC) and serves as host to the 92nd Air Refueling Wing. The Base also is the current home of the 141st Air Refueling Wing of the Washington Air National Guard (WANG), aircraft operational facilities, a weapons storage area, and a survival training school. Base operations employ approximately 5,000 civilian and military personnel (ES, 1994a).

Site FT-1 is a former fire training area located near the eastern property boundary of the Base between Taxiway 10 and Perimeter Road (Figure 1.3). Surface features at the site include a concrete fire training building (Building 1570), a subsurface confined-space-entry training vault, and a concrete slab. A large gravel pad surrounds all of these surface features. A lined fire pit is located immediately south of Building 1570 (Figure 1.3). The pit was constructed in 1970 using bermed gravel, and a mock aircraft is located in the center of the pit. Prior to 1970, fire training exercises were performed in an unlined pit formerly located immediately north of the current lined fire training pit, near Building 1570. A 4,000-gallon underground storage tank (UST) located east of Building 1570 was used to store fuels used in fire training exercises. Pressure tests performed on this tank in 1989 did not indicated the presence of potential leaks. Additionally, an oil/water separator is located within the gravel pad approximately 150 feet east of the current training pit. It was used to separate unburned fuels from water that remained in the training pit after training exercises were conducted. A poorly defined manmade ditch receives effluent from the oil/water separator and discharges in a wide, flat, marshy area where outfall infiltrates the ground surface (HNUS, 1993a).

Fire training exercises were conducted on a regular basis at FT-1 until operations were ceased in August 1991. Recent exercises consisted of filling the training pit with 2 to 3 inches of water and spraying approximately 300 gallons of uncontaminated fuel hydrocarbons over the top of the water. The fuel was then ignited and aqueous film-forming foam (AFFF) was applied to extinguish the fire. In recent exercises only uncontaminated fuels were used. However, during historical exercises, waste fuels and



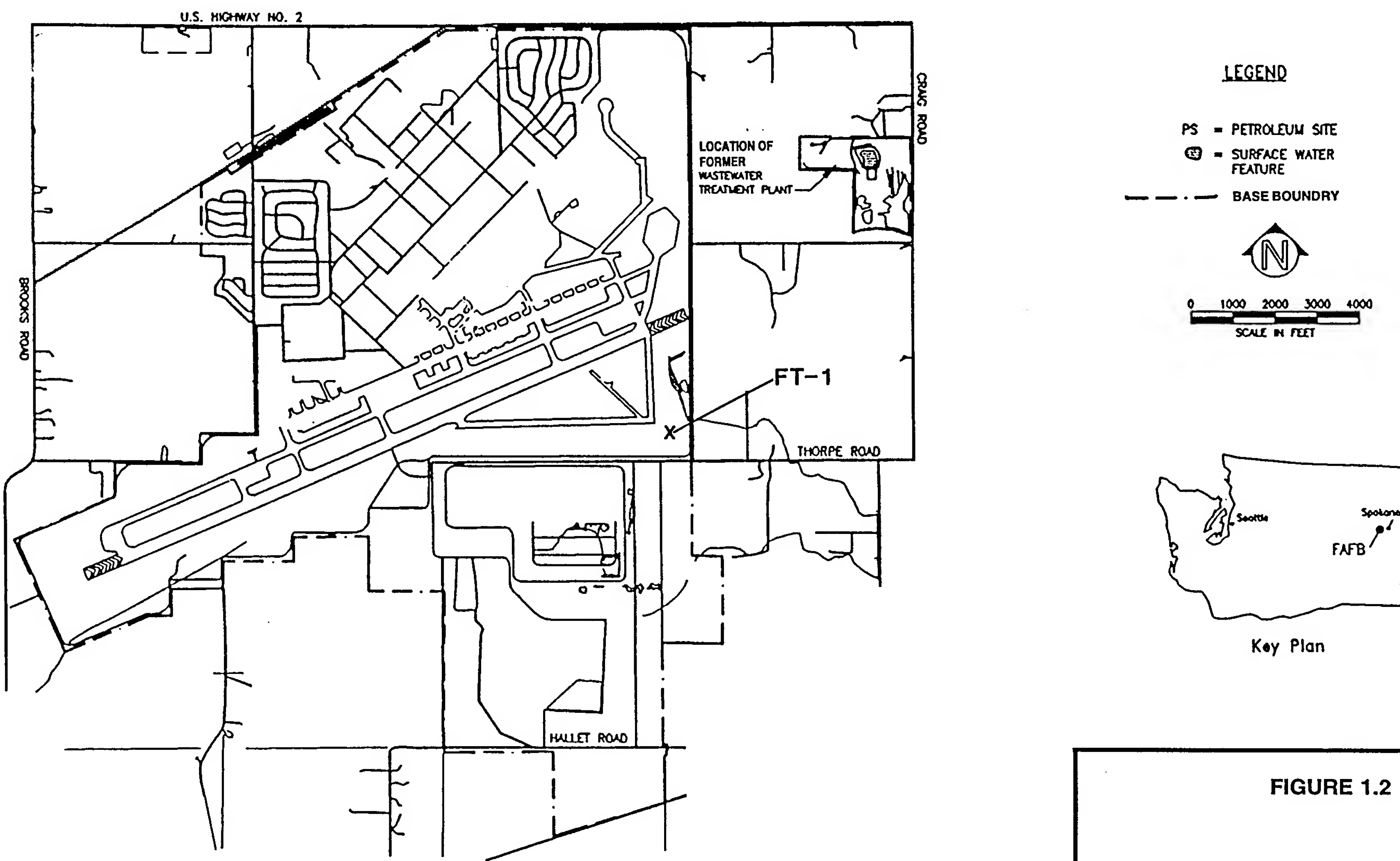
Source: ICF Technology Inc., 1995.

FIGURE 1.1

BASE LOCATION

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



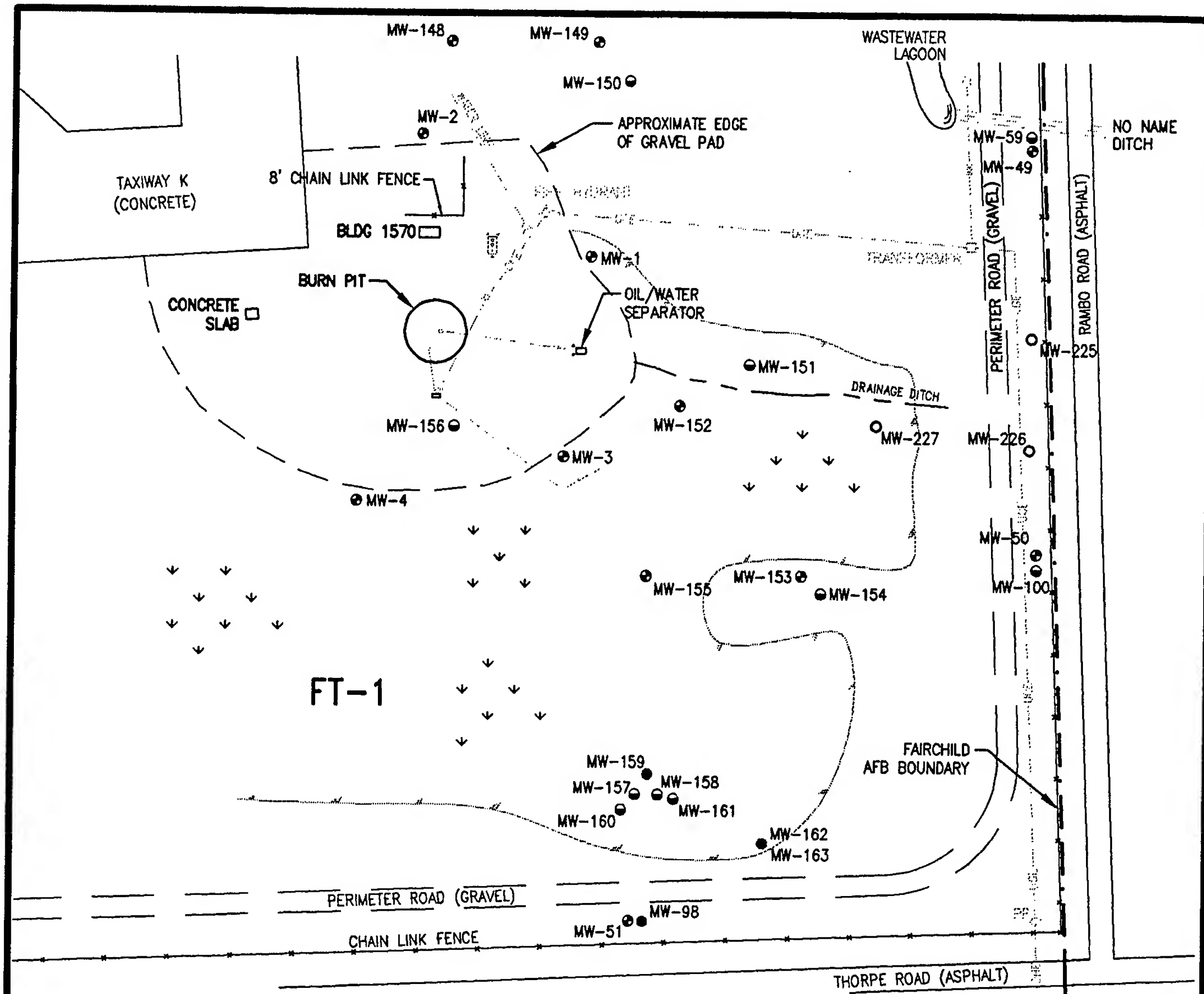
Source: ICF Technology Inc., 1995.

FIGURE 1.2

SITE LOCATION

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



N

0 100 200 400

FEET

LEGEND

- SHALLOW MONITORING WELL
- SHALLOW BEDROCK MONITORING WELL
- DEEP BEDROCK MONITORING WELL
- MONITORING WELL (SCREENED INTERVAL UNKNOWN)
- EXTENT OF WETLANDS
- CONFINED-SPACE FIRE TRAINING FACILITY

NOTE: WELLS MW-119, MW-121, MW-123, MW-124 AND MW-125 ARE LOCATED EAST OF THE SITE AND ARE NOT SHOWN HERE

FIGURE 1.3

SITE LAYOUT

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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other types of hazardous waste substances were used. The nature of these other wastes was not described in previous reports reviewed during the development of this work plan (HNUS, 1993a).

Investigations were initiated at FT-1 as a result of Installation Restoration Program (IRP) Phase 1 Record Search conclusions (JRB Associates, 1985). The presence of groundwater contamination was confirmed in the IRP Phase II Confirmations/Quantification study performed by Battelle Denver Operations (1989). Since that time, a remedial investigation (RI) has been completed by HNUS (1993), an analytical informal technical information report (ITIR) for long-term groundwater monitoring has been submitted by EA Engineering, Science, and Technology and Montgomery Watson Americas, Inc. (ES&T and MWA, 1995), and a remediation pilot study is currently being performed (ES, 1994b).

To date, soil contamination has been detected near the current fire training pit and near the outfall of the oil/water separator. Dissolved BTEX contamination also has been detected in groundwater samples collected near the current fire training pit. Additionally, dissolved CAH contamination has been detected at low concentrations, typically less than 5 micrograms per liter (µg/L), in samples collected from groundwater underlying the site and as far as 5,500 feet downgradient from the site. Dissolved BTEX concentrations, have been measured at concentrations significantly higher than dissolved CAH concentrations, with total dissolved BTEX concentrations as high as 1,320 µg/L measured in groundwater samples collected during previous investigations. The presence of mobile LNAPL (i.e., free product) or dense nonaqueous-phase liquid (DNAPL) has not been detected during previous site investigations.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Previously reported site-specific data were reviewed and used to develop a conceptual site model (CSM) for the groundwater flow and contaminant transport conditions at FT-1. The CSM guides the development of sampling locations and analytical data requirements needed to support the modeling efforts and to evaluate remediation technologies, including intrinsic remediation. Section 2.1 presents a synopsis of available site characterization data. Section 2.2 presents the preliminary conceptual groundwater flow and contaminant transport model that was developed based on these data.

2.1 DATA REVIEW

The following sections are based upon review of data from the following sources:

- IRP Remedial Investigation Report (HNUS, 1993a);
- IRP Record of Decision On-Base Priority One Operable Units (Sites SW-1, IS-1, OU-1 (PS-2, PS-6, AND PS-8), FT-1 AND WW-1) (HNUS, 1993b);
- IRP Remedial Design Work Plan for Fire Training Area FT-1, Fairchild AFB, Washington (ES, 1994a)
- IRP Baseline Data Bioventing and Air Sparging Treatability Test Letter Report, Site FT-1, Fire Training Facility, Fairchild AFB, Washington (Parsons ES, 1994b);
- Addendum to the IRP Baseline Data Bioventing and Air Sparging Treatability Test Letter Report Site FT-1, Fire Training Facility, Fairchild AFB, Washington (Parsons ES, 1995);
- Analytical ITIR: Long-Term Monitoring, April 1995 Sampling Craig Road Landfill and Priority Sites SQ-1, PS-2, PS-8, and FT-01 (ES&T and MWA, 1995); and
- Long-Term Monitoring Report For Priority 1 Sites SW-1 (LF-01), PS-2 (SS-18), and PS-8 (SS-26) at Fairchild AFB, Washington (ICF Technology, Inc., 1995).

Several other reports contain site information that may be useful during the development of fate and transport models. These documents, which were unavailable during the development of this work plan, include:

- Remedial Investigation/Feasibility Study (RI/FS) Site Characterization Summary Report Priority 1 Sites Fairchild AFB [Science Applications International Corporation (SAIC), 1990];

- IRP Phase II, Stage 1 Confirmation/Qualification, Stage 1 Fairchild AFB (Battelle Laboratories, 1985); and

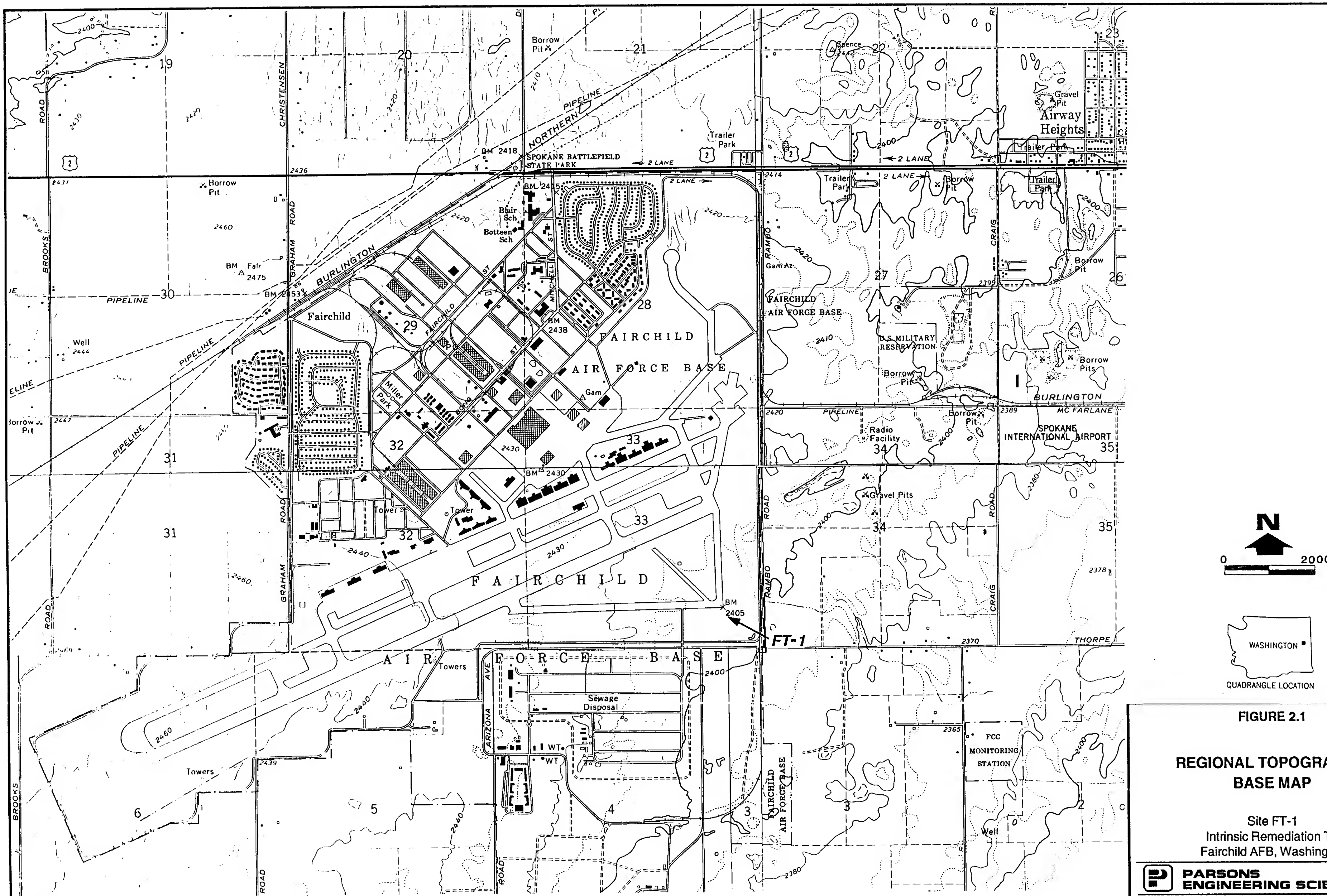
- IRP Phase I Records Search, 92nd Bombardment Wing, Fairchild AFB (JRB Associates, 1985).

2.1.1 Topography, Surface Hydrology, and Climate

Fairchild AFB is located within the Columbia Basin in the northeastern corner of the 55,000-square-mile Columbia Plateau Physiographic Province (ICF Technology Inc., 1995). The Columbia Plateau is bordered by mountains and highlands on all side. The northern edge of the Plateau gives way to the Okanogan Highlands roughly 75 miles north of Fairchild AFB, while the eastern end of the Plateau is bordered by the Rocky Mountains, approximately 75 miles east of Fairchild AFB. The Plateau extends approximately 250 miles to the south and west of the Base. The Blue Mountains border the Plateau on the south, and the Cascade Mountains border the Plateau on the west. There is a watershed divide in the center of the Plateau that causes streams north of this divide to flow in a northerly direction, and streams south of the divide to flow in a southerly direction. The topography of the region was shaped by glacial flood waters that eroded the surface of the Columbia Plateau during the Pleistocene Epoch (approximately 22,000 years ago) (HNUS, 1993a). The surface topography of the Base and surrounding region is generally flat to gently rolling grasslands sloping slightly to the east-northeast. Ground surface elevations on the Base range from 2,400 to 2,460 feet above mean sea level (ft msl) (Figure 2.1).

Fairchild AFB is located in the northern half of the Columbia Plateau, north of the watershed divide. All surface water drainage in this region of the Columbia Plateau generally flows to the north or northwest (Flint, 1936). The Base is approximately 7 miles west-southwest of the Spokane River, which flows through the city of Spokane [US Geological Survey (USGS), 1973a, 1973b, 1986a, and 1986b]. Two other drainages in the vicinity of the Base are Deep Creek and Marshall Creek, located approximately 2 miles northwest and 8 miles southeast of the Base, respectively. These creeks flow northwest and join the Spokane River, which drains this region of the Plateau. Surface water on the Base is generally limited to precipitation runoff and intermittent flow in No Name Ditch near the eastern boundary of the Base just north of FT-1. Precipitation runoff is controlled within a series of manmade ditches. Reportedly, water collected in the ditch system does not leave Base property, and surface water either infiltrates the subsurface or evaporates (HNUS, 1993a).

At FT-1, storm precipitation is reported to infiltrate into the ground. A manmade drainage ditch extends approximately 300 feet eastward from the oil/water separator on the eastern edge of the training pit and terminates in a broad flat marshy area. The oil/water separator treated discharge generated during fire training exercises. Fire training exercises ceased at the site in 1991, and the oil/water separator is currently



Source: USGS, 1973a, 1973b, 1986a, and 1986b.

FIGURE 2.1

REGIONAL TOPOGRAPHIC BASE MAP

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.

inactive. Snowmelt runoff was observed in the ditch during the RI activities (HNUS, 1993a).

Fairchild AFB is surrounded by semi-arid grasslands common to this area of the Columbia Basin. The Base receives approximately 16 inches of rainfall during the warm dry summers, and 40 inches of snowfall during the cool, damp winter months. The prevailing wind direction in the region is to the northeast at an average speed of 8 miles per hour (ICF Technology, Inc., 1995). The average evapotranspiration rate for the region is reported at 12.8 inches per year (JRB Associates, 1985). Maximum infiltration rates usually occur during the early spring when snow melt runoff combines with precipitation while temperatures are still cool and evapotranspiration is low (HNUS, 1993a).

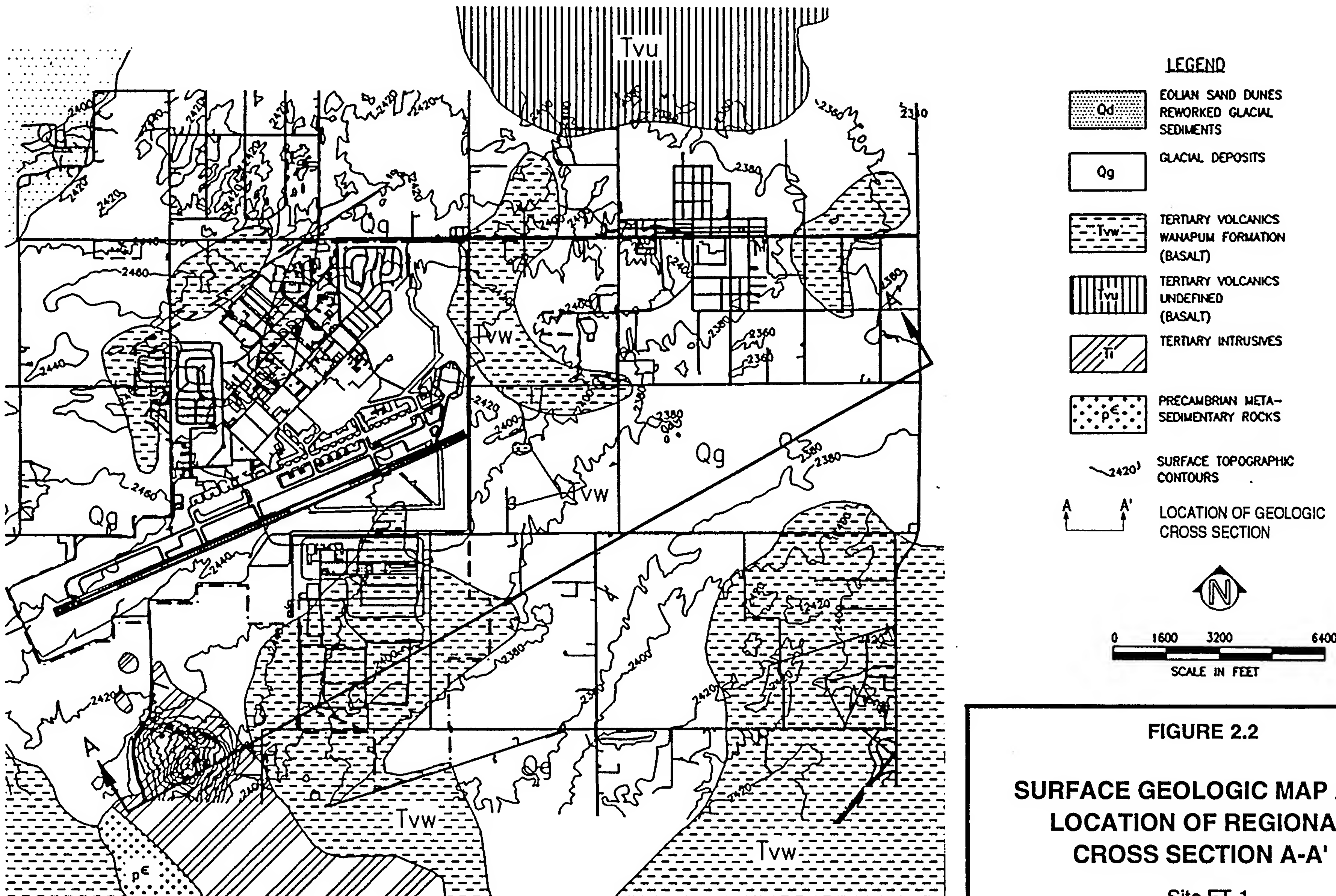
2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Regional Geology and Hydrogeology

The shallow subsurface geology at Fairchild AFB is a mixture of Quaternary sediments consisting of eolian, glacial, fluvial, lacustrine deposits (Figure 2.2). Flood waters from the glacial-era Missoula Lake scoured the basalt bedrock of this region of the Columbia Plateau. Coarse sediments were deposited during the early recession of flood waters, followed by finer sediments during the later stages of floodwater recession. The alluvium in the vicinity of the Base generally consists of fine-grained sediments deposited by receding glacial flood waters. Clays and silts are intermixed with sandy silts, clays, and gravels (HNUS, 1993a). Additionally, loess (windblown silt) deposits are interbedded in portions of the unconsolidated deposits. Unconsolidated deposits generally follow the slope of the underlying basalt bedrock (ICF Technology, Inc., 1995).

Bedrock in the vicinity of the Base is mostly Tertiary basalts of the Columbia River Group. Basalts below Fairchild AFB are of the Wanampum Formation (HNUS, 1993a). The basalt flows in the region are interbedded with sedimentary clay and silt units of the of the Latah Formation. These layers were deposited when stream beds were isolated by the volcanic basalt flows (Cline, 1969). The Wanampum Basalt flow below the Base appears to be divided into an upper and lower flow sequence by an interbed of the Latah Formation (Figure 2.3). The upper basalt flow is 166 feet to 193 feet thick across the Base. The surface of the upper basalt flow is vesiculated, deeply fractured, and highly weathered in places. Just east of the Base the upper basalt layer was completely eroded away by the Missoula Lake flood waters. The middle of this flow contains few vesicles and fractures; the formation becomes more massive and competent with depth. The underlying Latah Formation deposits consist of an extensive silty claystone that ranges in thickness from 8.5 to 10 feet (HNUS, 1993a). Information on the geologic characteristics of the lower basalt flow was not available in the previous reports reviewed as part of this work plan; however, information on the lower basalt flow is not considered to be vital to the formation of the CSM for data collection to evaluate intrinsic remediation at FT-1.

Groundwater in the vicinity of the Base is encountered from 8 to 12 feet below ground surface (bgs) and is found in both the unconsolidated material and the



Source: ICF Technology Inc., 1995.

FIGURE 2.2

SURFACE GEOLOGIC MAP AND LOCATION OF REGIONAL CROSS SECTION A-A'

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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Denver, Colorado

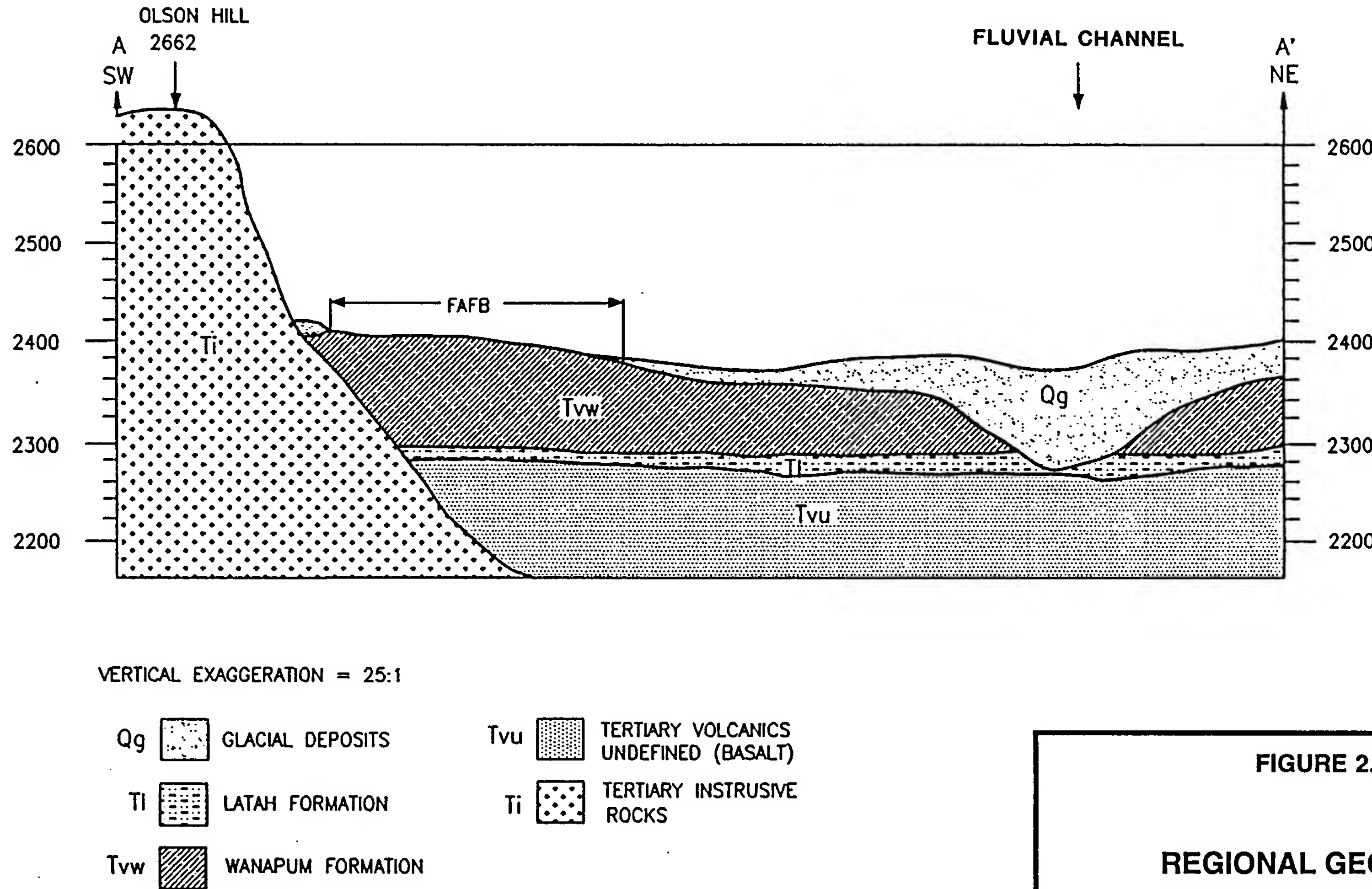


FIGURE 2.3

REGIONAL GEOLOGIC CROSS SECTION A-A'

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

Source: ICF Technology Inc., 1995.

underlying basalt bedrock. Groundwater flow in the unconsolidated deposits is through intergranular pore space, while flow in the basalt is through interconnecting fractures (HNUS, 1993a). Flow across the Base is generally to the east and east-northeast, but local variations may result from local changes in bedrock topography (Figure 2.4). Groundwater in the unconsolidated material and shallow bedrock is generally unconfined, with some local semiconfined areas. The unconsolidated material and the shallow basalt are hydraulically connected by fractures, vesicles, and weathered zones. The middle region of the shallow basalt flow is more competent with less fracturing, and acts as an aquitard. The interbedded claystone between the basalt flows also acts as a confining layer (HNUS, 1993a).

Recharge of the aquifer under the Base is expected to come from upgradient flow and surface runoff infiltration. Groundwater in the shallow aquifer in the vicinity of the Base is not known to be used as a drinking water supply. Neighborhoods to the east and northeast of the Base obtain domestic and agricultural water primarily from private wells which tap aquifers in the deeper basalt flows. The closest residential neighborhoods are roughly 1,800 feet east (downgradient) of the site. Base drinking water is primarily supplied from a Base-owned well field 10 miles northwest of the Base. Additionally, there is a water supply well located in the southern area of the Base. This well also produces water from the basalt aquifer and supplies roughly 10 percent of the Base's needs (HNUS, 1993a).

2.1.2.2 FT-1 Geology and Hydrology

Site geology and hydrogeology descriptions are summarized principally from descriptions provided in the RI (HNUS, 1993a). Surface soils at the site primarily consist of Cheney and Uhlig Series clayey silts, and the description of subsurface soils underlying FT-1 is relatively consistent with the regional geology described in Section 2.1.2.1. Unconsolidated material overlying the basalt bedrock ranges in thickness from 9 feet to 30 feet across the site. Shallow deposits at FT-1 are primarily silty clays and clayey silts with sands, while deeper unconsolidated material appears to be coarser-grained and consists of silty sands and gravels. Unconsolidated material overlies two distinct basalt flows that are separated by a Latah Formation sedimentary interbed. Geologic cross sections B-B' and C-C' depict the unconsolidated material and shallow regions of the upper basalt bedrock underlying the site. The locations of these cross sections are shown on Figure 2.5, with cross section A-A' presented on Figure 2.6 and cross section B-B' presented on Figure 2.7.

Geologic features of the shallow basalt flow, sedimentary interbed, and upper portion of the deeper basalt flow underlying FT-1 were investigated during the installation of a cored hole later completed as MW-159. Packer tests were performed at 10-foot intervals during the installation of this hole. Results of the packer testing performed at FT-1 are presented in Table 2.1. The shallow basalt flow is estimated to be 192 feet thick and to extend to a depth of 207 feet bgs. The upper 50 feet of the shallow basalt flow is described as being massive weathered basalt with small vesicles and slight to moderate fracturing. The middle portion of the upper basalt flow becomes more dense with fewer vesicles and hairline fractures existing from 65 to 180 feet bgs. From 180 feet to 205 feet bgs, the flow is described as relatively nonfractured and nonvesicular massive basalt. The bottom few feet of the upper basalt flow, near the

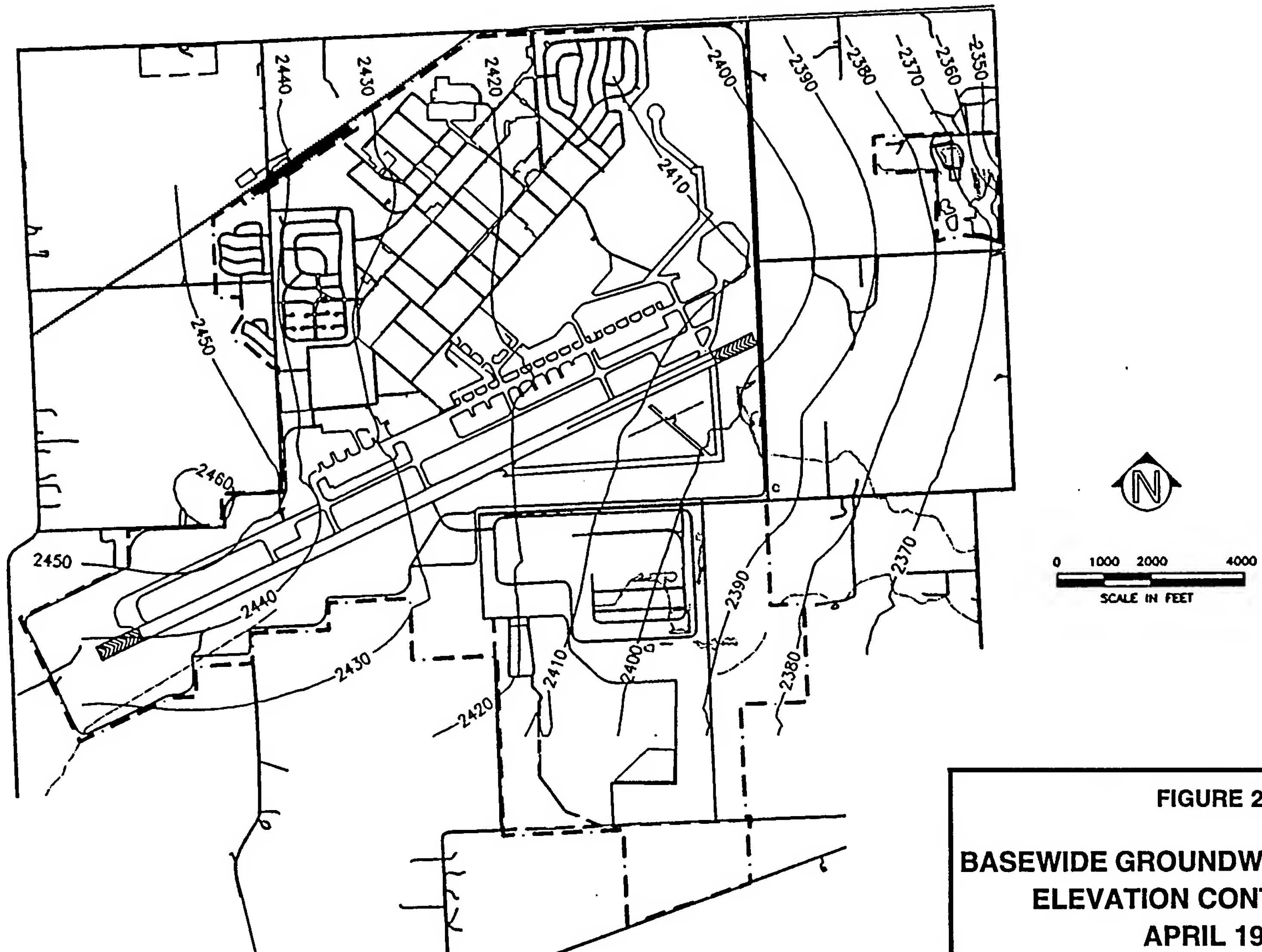


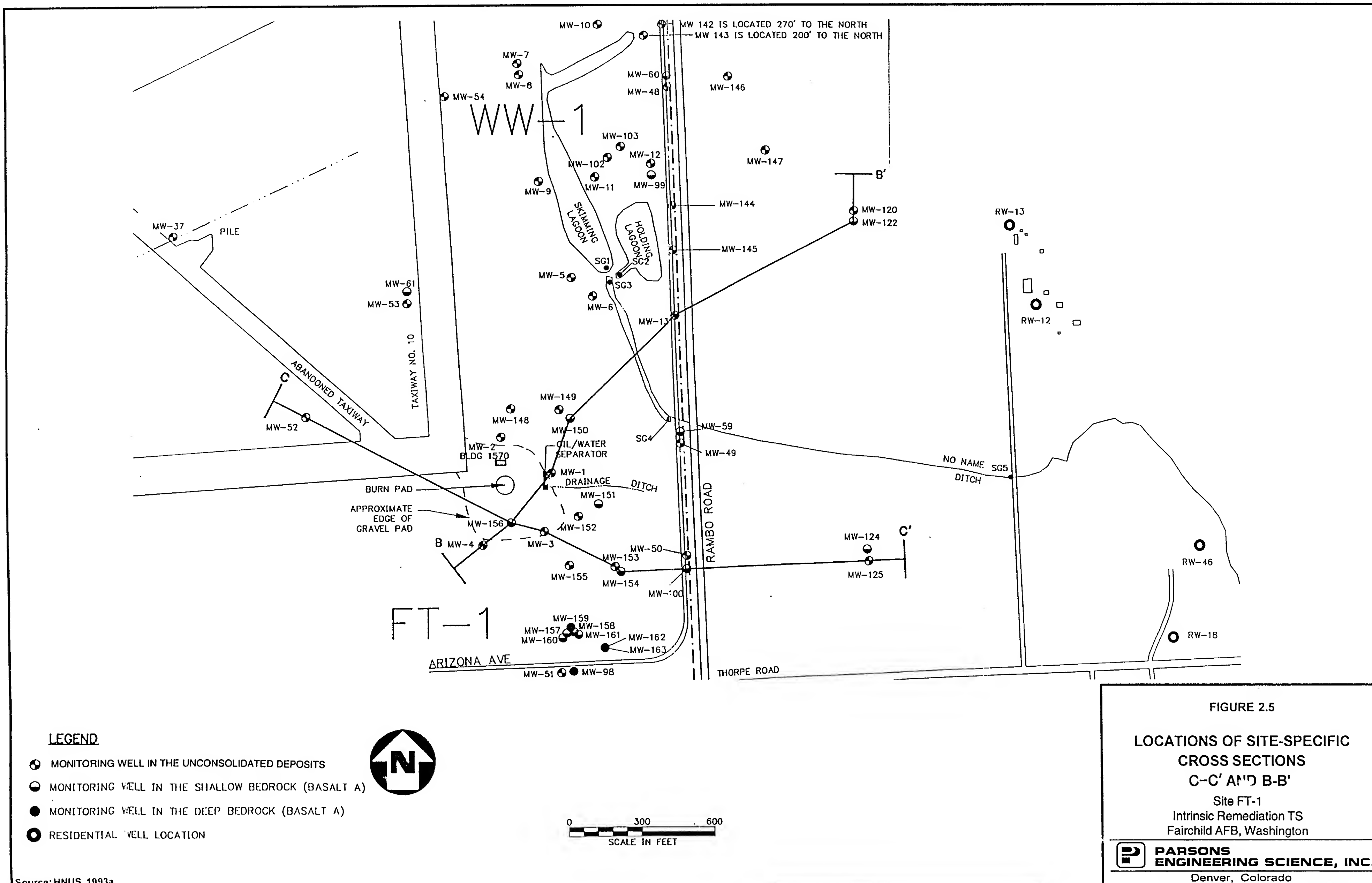
FIGURE 2.4

BASEWIDE GROUNDWATER SURFACE ELEVATION CONTOUR MAP
APRIL 1993

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

Source: ICF Technology Inc., 1995.



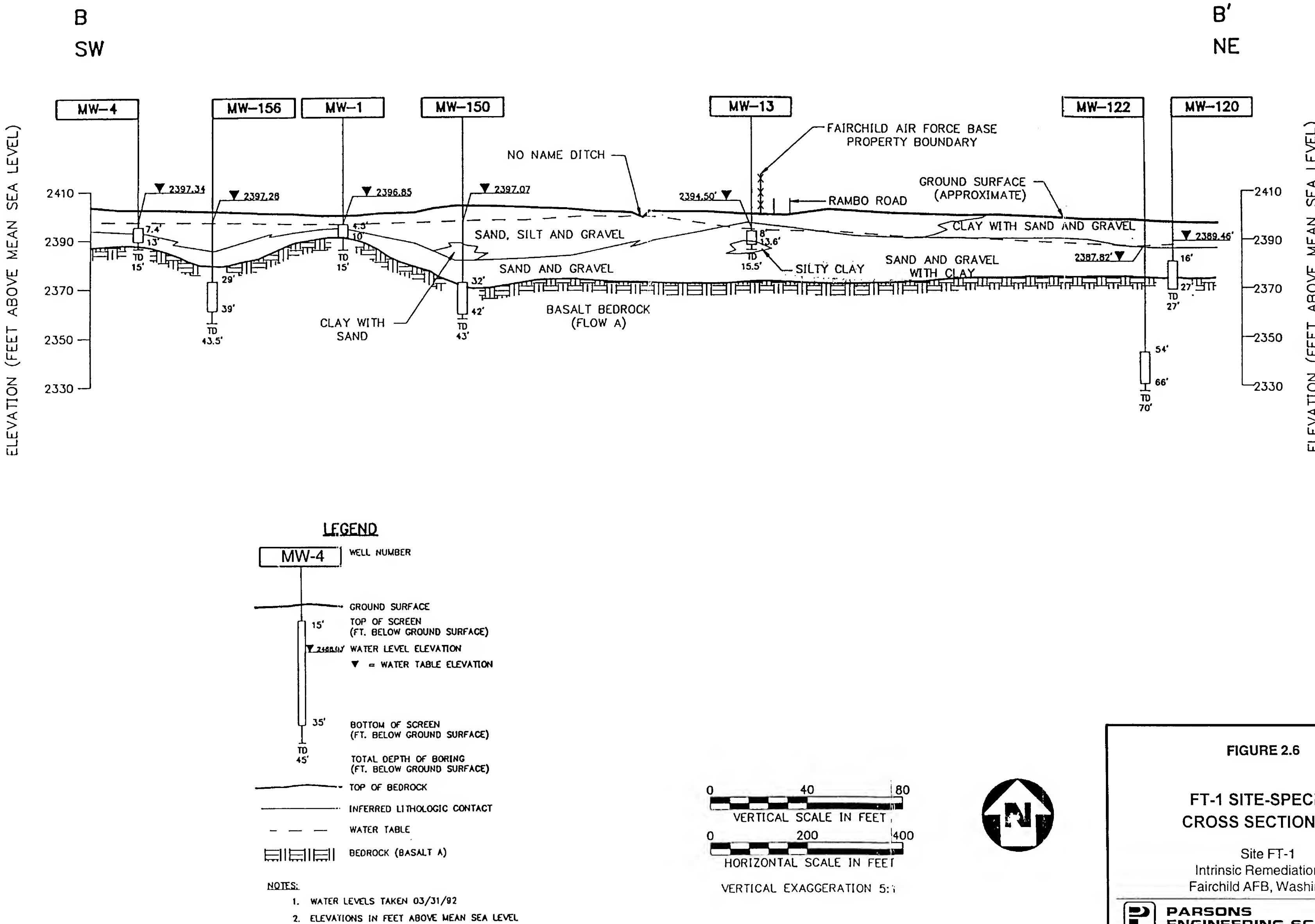
Source: HNUS, 1993a.

FIGURE 2.5

LOCATIONS OF SITE-SPECIFIC CROSS SECTIONS C-C' AND B-B'

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



Source: HNUS, 1993a.

FIGURE 2.6

FT-1 SITE-SPECIFIC CROSS SECTION B-B'

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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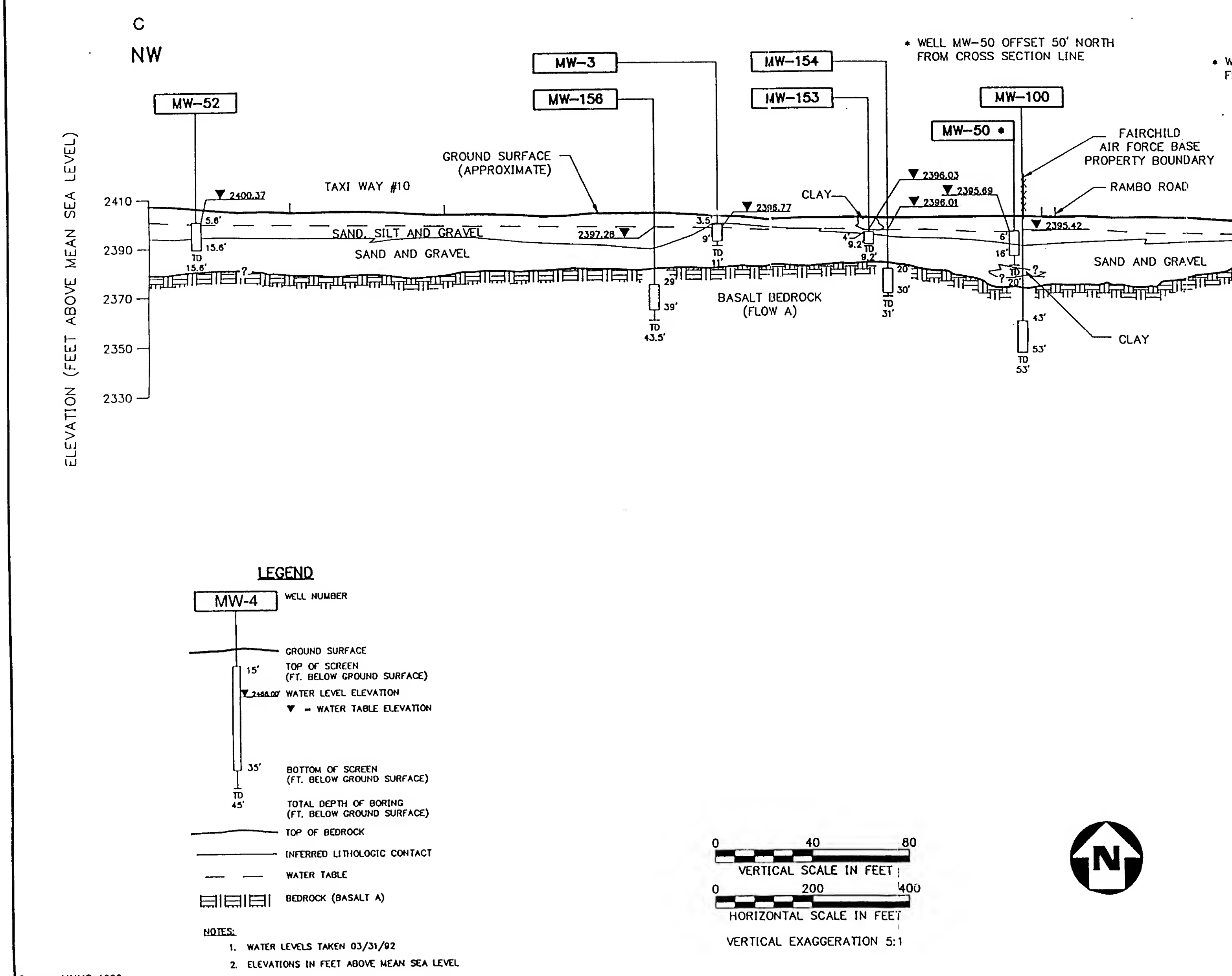
Denver, Colorado



Source: HNUS, 1993a.

FIGURE 2.7

FT-1 SITE-SPECIFIC CROSS SECTION A-A'

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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TABLE 2.1
SUMMARY OF PACKER TEST RESULTS PERFORMED DURING INSTALLATION OF MW-159
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Dept Interval (feet bgs)	Formation	Bulk Hydraulic Conductivity (K) (ft/day)
20-30	Basalt A	2.66
25-35	Basalt A	2.56
35-45	Basalt A	0.02
45-55	Basalt A	0.01
55-65	Basalt A	0.02
65-75	Basalt A	0.04
75-85	Basalt A	0.02
85-95	Basalt A	0.03
95-105	Basalt A	0.02
106-116	Basalt A	0.02
105-115	Basalt A	0.03
115-125	Basalt A	0.05
125-135	Basalt A	0.09
135-145	Basalt A	0.32
145-155	Basalt A	0.33
155-165	Basalt A	0.32
160-170	Basalt A	0.33
165-175	Basalt A	0.30
175-185	Basalt A	0.31
185-195	Basalt A	0.34
197-202	Basalt A	0.58
202-207	Basalt A	0.52
207-212	Interbed A	0.60
209-214 [/a]	Interbed A	0.60
216-221	Basalt B	0.82
222-227	Basalt B	0.52

[a/] The 214- to 216-foot interval was not tested to avoid bridging the Interbed A and Basalt B interface.

Latah interbed, becomes more vesicular. The Latah Formation interbed separating the upper and lower basalt flows is approximately 8.5 feet thick and extends from 207 feet bgs to 215.5 feet bgs. This interbed consists of silty claystone with deposits of organic material. The upper portion of the deep basalt flow is described as highly vesicular with a moderate to high number of fractures and minor weathering. Deeper portions of the lower basalt flow had not been investigated in reports reviewed during the development of this work plan.

There are currently 39 groundwater monitoring wells associated with FT-1, including 18 wells screened in the unconsolidated deposits and 18 wells screened in the basalt bedrock. Construction details for three monitoring wells, MW-225, MW-226, and MW-227, were not available in reports reviewed during the development of this work plan. Groundwater at the site resides in the Quaternary glacial deposits and in the underlying upper basalt bedrock. Available monitoring well construction details and select well level data are presented in Table 2.2. Figure 2.8 shows the groundwater surface for FT-1 in March 1992.

In the immediate vicinity of the site, groundwater flows to the east-southeast, which is consistent with the regional flow direction. Groundwater elevations measured in March 1992 indicate the average hydraulic gradient across FT-1 is approximately 0.002 foot per foot (ft/ft); however, the hydraulic gradient in the source area and immediately east of Rambo Road is somewhat steeper, at 0.007 ft/ft (Figure 2.8) (HNUS, 1993a). Fluctuations of up to 9 feet were observed in monitoring well data collected from February 1991 to April 1992 (HNUS, 1993a). Typically, groundwater elevations at Fairchild AFB are lower during August through November, and higher during April through July (ICF Technology, Inc., 1995).

Six unconsolidated deposits/shallow bedrock groundwater monitoring wells pairs (MW-49 and MW-59; MW-149 and MW-150; MW-50 and MW-100; MW-153 and MW-154; MW-157 and MW-158; and MW-53 and MW-61) were installed to investigate vertical hydraulic gradients and the vertical extent of contamination in groundwater underlying FT-1. Groundwater elevation data collected in 1991 and 1992 suggest downward vertical gradients of 0.006, 0.01, 0.006, and 0.0006 ft/ft for monitoring well pairs MW-49 and MW-59, MW-149 and MW-150, MW-50 and MW-100, and MW-157 and MW-158, respectively. Water elevations measured within the groundwater monitoring wells MW-154 and MW-153 did not indicate the presence of a vertical gradient near this pair (HNUS, 1993a). In 1992, the maximum downward vertical gradient was measured at 0.58 ft/ft between wells MW-53 and MW-61. Basalt bedrock well MW-61 exists in a high-yielding fracture zone. Because of the large differences in hydraulic heads between well MW-61 and the nearby unconsolidated deposit well and other site wells screened between 60 and 70 feet bgs in the basalt bedrock, it is believed that the fracture zone at MW-61 is hydraulically isolated from other site wells of similar or shallower depth.

Large differences in groundwater elevations were observed between all well pairs screened in the shallow bedrock and in the deeper regions of the upper basalt flow. In 1992, groundwater elevations measured in deep bedrock monitoring wells MW-159, MW-98, and MW-163 were 172 feet, 80 feet, and 169 feet lower than measurements collected from MW-51 the nearest shallow well. These differences appear to indicate

TABLE 2.2
SUMMARY OF WELL INSTALLATION DETAILS AND SELECT GROUNDWATER ELEVATION DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Well Identification	Sampling Event or Date	Depth to Bottom of Well (feet bgs)[a/]	Screened Interval (feet bgs)	Elevation of Reference Point for Measurements (feet msl)[b/]	Depth to groundwater (feet)	Groundwater Elevation (feet msl)	Source[c/]
MW-1	2/91	15	4.5-10	2404.06	7.01	2397.05	1
	3/92	NA[d/]		2404.06	7.21	2396.85	1
	4/95	13.55		NA	5.26	NA	2
MW-2	2/91	14	6.3-11.8	2406.95	7.94	2399.01	1
	3/92	NA		2406.95	7.95	2399	1
	4/95	13.55		NA	4.28	NA	2
MW-3	2/91	11	3.5-9	2403.61	6.54	2397.07	1
	3/92	NA		2403.61	6.84	2396.77	1
	4/95	13.5		NA	5.16	NA	2
MW-4	2/91	15	7.35-12.85	2404.93	7.37	2397.56	1
	3/92	NA		2404.93	7.59	2397.34	1
	4/95	14.4		NA	5.54	NA	2
MW-6	2/91	17.5	5.8-16.75	2406.45	9.87	2396.58	1
	3/92	NA		2406.45	10.02	2396.43	1
MW-13	2/91	15.5	8.05-15.55	2404.35	9.87	2394.48	1
	3/92	NA		2404.35	9.85	2394.5	1
MW-49	2/91	13	8-13	2400.95	5.84	2395.11	1
	3/92	NA		2400.95	6.11	2394.84	1
MW-50	2/91	20	6-16	2400.22	4.24	2395.98	1
	3/92	NA		2400.22	4.53	2395.69	1
	4/95	17.45		NA	3.7	NA	2
MW-51	2/91	10	5-10	2400.77	3.87	2396.9	1
	1/92	NA		2400.77	5.9	2394.87	1
	3/92	NA		2400.77	4.13	2396.64	1
MW-52	2/91	15.6	5.6-15.6	2409.31	9.41	2399.9	1
	3/92	NA		2409.31	8.94	2400.37	1
MW-53	2/91	21.6	11.5-21.5	2409.75	10.15	2399.6	1
	3/92	NA		2409.75	10.05	2399.7	1
MW-59	2/91	73.5	59.5-70	2401.2	6.45	2394.75	1
	3/92	NA		2401.2	6.73	2394.47	1
MW-61	2/91	72	59.5-70	2408.63	37.64	2370.99	1

TABLE 2.2 (Continued)
SUMMARY OF WELL INSTALLATION DETAILS AND SELECT GROUNDWATER ELEVATION DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Well Identification	Sampling Event or Date	Depth to Bottom of Well (feet bgs)[a/]	Screened Interval (feet bgs)	Elevation of Reference Point for Measurements (feet msl)[b/]	Depth to groundwater (feet)	Groundwater Elevation (feet msl)	Source[c/]
MW-61 (cont.)	3/92	NA		2408.63	37.07	2371.56	
MW-98	2/91	203.46	193.13-203.46	2400.14	86.88	2313.26	1
	1/92	NA		2400.14	85.3	2314.84	1
	3/92	NA		2400.14	84.18	2315.96	1
MW-100							
	2/91	53.43	43.1-53.43	2400.36	4.69	2395.67	1
	3/92	NA		2400.36	4.94	2395.42	1
	5/95	NA		NA	4.14	NA	2
MW-104							
	2/91	9.24	3.99-9.24	2402.37	3.94	2398.43	1
	3/92	NA		2402.38	4.17	2398.21	1
MW-119							
	6/91	204	191-201.74	NA	59.55	NA	1
MW-121							
	1/92	22	6-16.3	NA	NA	2380.1	1
	3/92	NA		2388.34	7.85	2380.49	1
MW-123							
	1/92	17	7-17	NA	NA	2384.93	1
	3/92	NA		2394.13	8.07	2386.06	1
MW-124							
	6/91	55.7	44.7-55.7	NA	7.12	NA	1
	3/92	NA		2397.89	6.69	2391.26	1
MW-125							
	6/91	16	4.5-14.5	NA	5.55	NA	1
	3/92	NA		2397.78	7.87	2389.91	1
MW-148							
	1/92	10	5-10	NA	NA	2396.56	1
	3/92	NA		2406.97	8.65	2398.32	1
MW-149							
	1/92	14	9-14	NA	NA	2396.04	1
	3/92	NA		2406.87	9.51	2397.36	1
MW-150							
	1/92	43	32-42	NA	NA	2395.77	1
	3/92	NA		2406.78	9.71	2397.07	1
MW-151							
	1/92	30.3	20-30	NA	NA	2395.03	1
	3/92	NA		2400.45	4.35	2396.1	1
	4/95	32.05		NA	3.1	NA	2
MW-152							
	1/92	12	7-12	NA	NA	2395.11	1
	3/92	NA		2402.23	5.92	2396.31	1
	4/95	13.45		NA	4.28	NA	2

TABLE 2.2 (Concluded)
SUMMARY OF WELL INSTALLATION DETAILS AND SELECT GROUNDWATER ELEVATION DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Well Identification	Sampling Event or Date	Depth to Bottom of Well (feet bgs)[a/]	Screened Interval (feet bgs)	Elevation of Reference Point for Measurements (feet msl)[b/]	Depth to groundwater (feet)	Groundwater Elevation (feet msl)	Source [c/]
MW-153	1/92	9.2	4-9	NA	NA	2394.88	1
	3/92	NA		2402.21	6.18	2396.03	1
	4/95	11.3		NA	5.14	NA	2
MW-154	1/92	30.3	20-30	NA	NA	2394.88	1
	3/92	NA		2401.52	5.51	2396.01	1
	4/95	32.57		NA	4.62	NA	2
MW-155	1/92	9	4-9	NA	NA	2395.08	1
	3/92	NA		2402.37	5.98	2396.39	1
	4/95	11.35		NA	4.52	NA	2
MW-156	1/92	39.3	29-39	NA	NA	2395.38	1
	3/92	NA		2405.35	8.07	2397.28	1
	4/95	41.7		NA	5.85	NA	2
MW-157	1/92	36	26-36	NA	NA	2394.96	1
	3/92	NA		2401.71	5.24	2396.47	1
	4/92	NA		2401.71	5.24	2396.47	1
MW-158	4/92	89.5	78.2-88.2	NA	NA	2396.44	1
	3/92	NA		2401.02	4.58	2396.44	1
MW-159	4/92	230	180-190	NA	NA	2223.2	1
	3/92	NA		2401.32	178.12	2223.2	1
MW-160	1/92	40	17-27	NA	NA	2395.04	1
	3/92	NA		2401.57	5.11	2396.46	1
MW-161	1/92	42	32-41.6	NA	NA	2394.02	1
	3/92	NA		2400.84	4.07	2396.77	1
MW-162	1/92	39	29-39	NA	NA	2394.35	1
	3/92	NA		2401.49	5.14	2396.35	1
MW-163	1/92	180.7	170.7-180.7	NA	NA	2225.62	1
	3/92	NA		2401.49	175.87	2225.62	1

Note: Additional groundwater elevation data can be found in Appendix M of RI report (HNUS, 1993a).

[a/] Feet bgs = feet below ground surface.

[b/] Feet msl = feet above mean sea level.

[c/] Sources:

1. HNUS, 1993a.
2. ES&T and MWA, 1995.

[d/] NA = Information not available.

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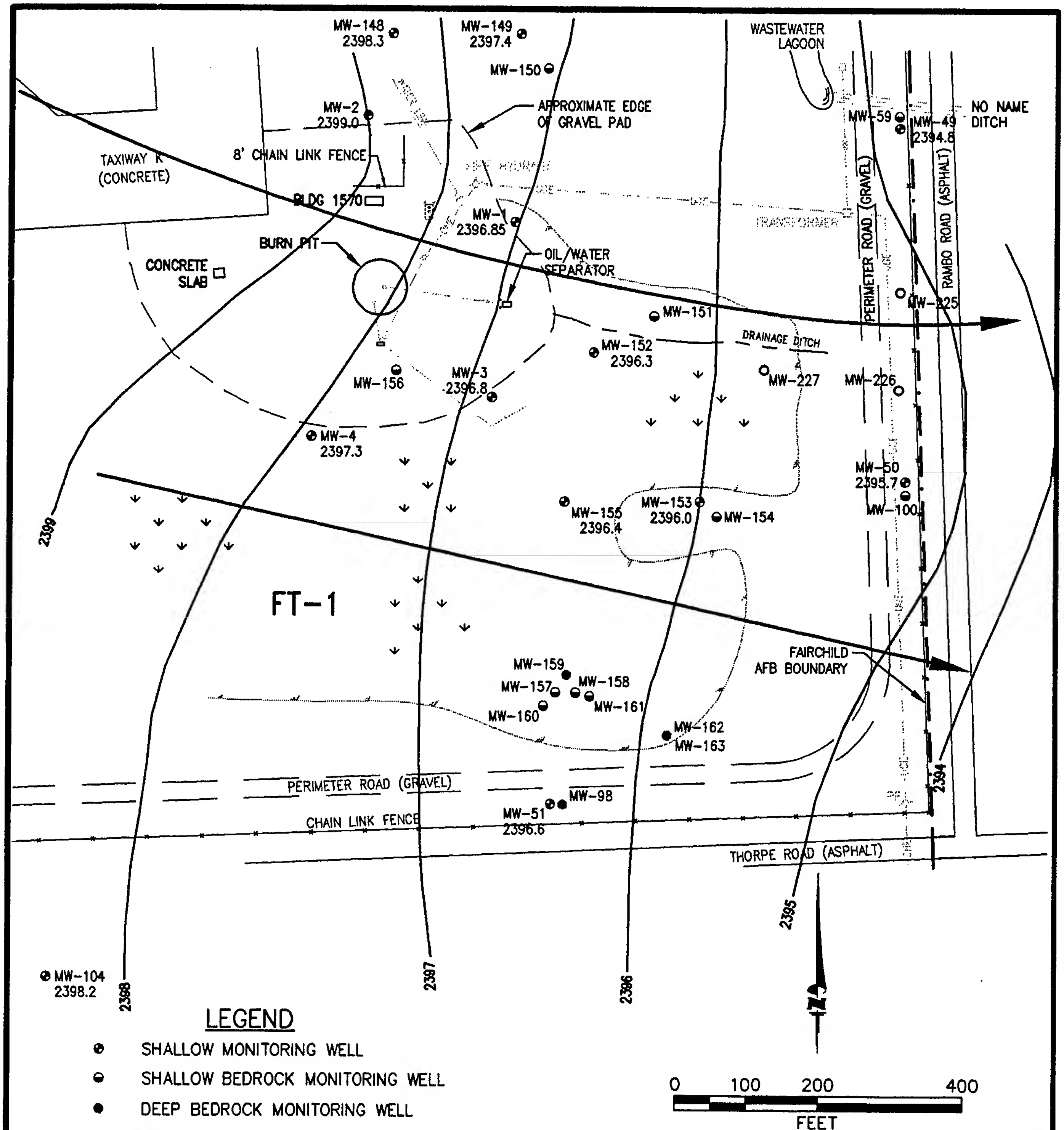

LEGEND

- SHALLOW MONITORING WELL
- SHALLOW BEDROCK MONITORING WELL
- DEEP BEDROCK MONITORING WELL
- MONITORING WELL (SCREENED INTERVAL UNKNOWN)

2398.2 GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL)

—2398— ESTIMATED CONTOUR OF EQUAL GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL)

GROUNDWATER FLOW DIRECTION

EXTENT OF WETLANDS

CONFINED-SPACE FIRE TRAINING FACILITY

NOTE: WELLS MW-119, MW-121, MW-123, MW-124 AND MW-125 ARE LOCATED EAST OF THE SITE AND ARE NOT SHOWN HERE

SOURCE: HNUS, 1993a.

FIGURE 2.8

GROUNDWATER SURFACE ELEVATIONS (MARCH 1992)

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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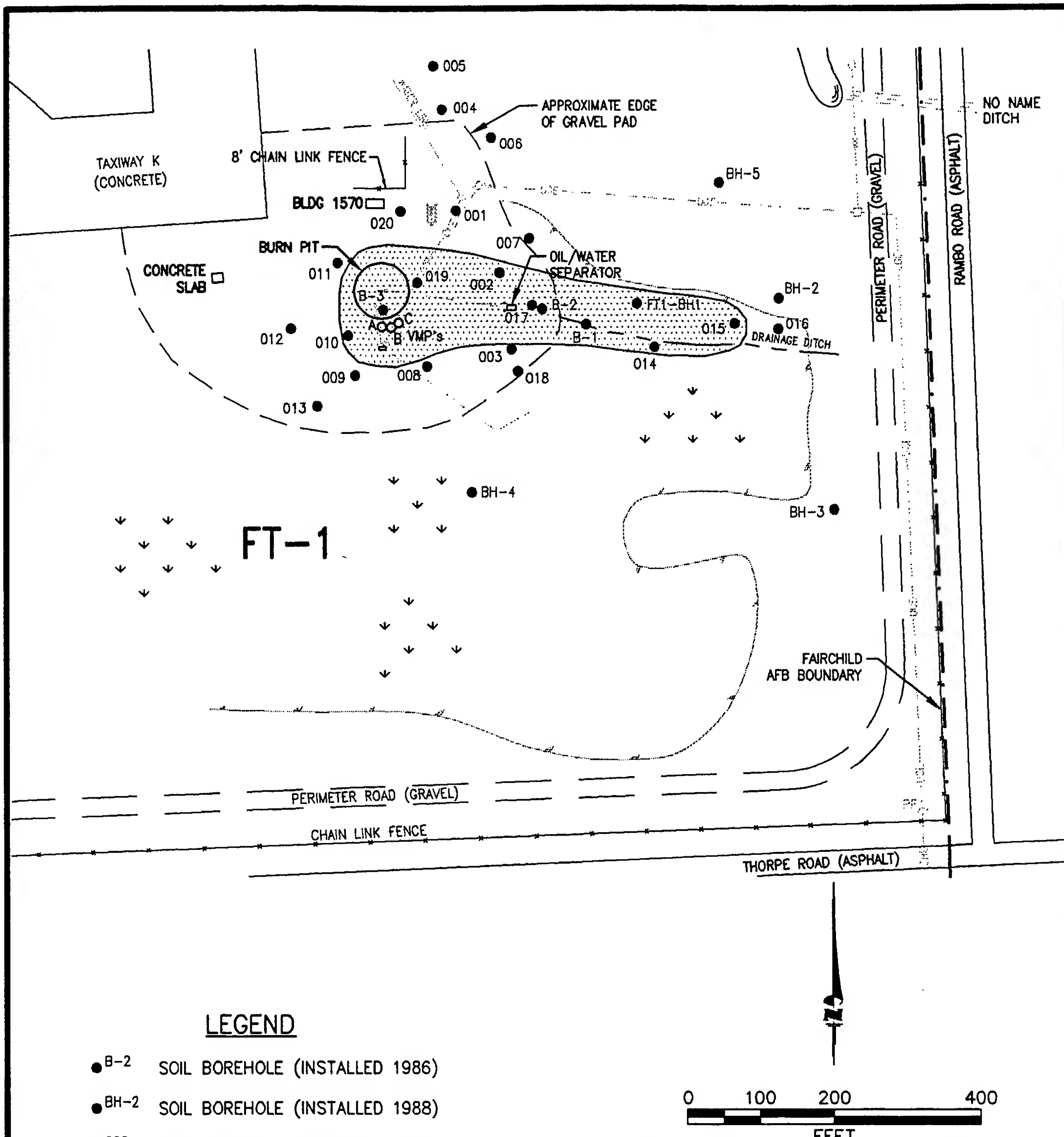
that groundwater in the unconsolidated deposits and the shallow bedrock is not in communication with groundwater in deeper regions of the bedrock. Generally, however, groundwater in the unconsolidated deposits and the shallow bedrock appears to be in hydraulic communication, with indications of a small downward hydraulic gradient.

Pumping tests were performed in the unconsolidated material monitoring wells MW-1 and MW-155, both of which are screened across gravely sand deposits. Drawdown was not observed during either test in the nearest observation wells MW-3 and MW-153, located approximately 170 feet and 187 feet from their respective pumping wells (Figure 2.5). A semilog analysis was used to estimate the hydraulic conductivities and transmissivities for the pumping tests performed at MW-1 and MW-155 (Theis, 1935). The hydraulic conductivities calculated from the pump test data are 418 feet per day (ft/day) at MW-1 and 37 ft/day at MW-155. Transmissivities were calculated at 2,410 square feet per day (ft^2/day) and 214 ft^2/day at wells MW-1 and MW-155, respectively (HNUS, 1993a). An additional pumping test was performed in the shallow bedrock well, MW-157. Drawdown was observed in wells MW-160 and MW-161 approximately 40 and 48 feet away from MW-157 (see Figure 2.5). The average hydraulic conductivity and average transmissivity calculated from drawdown data collected from the observation wells are 0.8 ft/day and 21.8 ft^2/day, respectively. Pumping tests could not be performed in the deeper regions of the upper basalt flow because sufficient pumping rates could not be sustained in installed pumping wells (HNUS, 1993a).

2.1.3 Summary of Analytical Data for FT-1

2.1.3.1 Soil Sampling and Analytical Results

Historical soil sampling data are available for sampling events that took place in 1986, 1988, 1990, and 1994. In 1986, six soil samples were collected from boreholes B-1 through B-3 installed at FT-1. Two years later, 20 additional soil samples were collected during the installation of monitoring wells MW-49 through MW-53 and boreholes BH-1 through BH-5. In 1990, 33 additional soil samples were collected from 20 additional soil boreholes, 001 through 020. In 1994, ES (1994b) collected seven soil samples during the installation of four vapor monitoring point (VMPs) at FT-1 (Figure 2.9). At a minimum, soil samples collected during these sampling events were analyzed for BTEX, trichloroethene (TCE), *cis*-1,2-dichloroethene (cDCE), *trans*-1,2-dichloroethene (tDCE), vinyl chloride (VC), and total petroleum hydrocarbon (TPH) data. The ROD specifies that benzene is the primary contaminant of concern at the site (HNUS, 1993b); however, BTEX, TPH, and TCE-related contaminants are all of interest for the intrinsic remediation demonstration for shallow groundwater underlying FT-1. Soil samples collected during previous investigations were analyzed for additional contaminants; however, results reported for additional contaminants are not of primary importance for completion of this TS and are not summarized in this work plan. Table 2.3 summarizes BTEX and TPH results for all soil samples collected during these sampling efforts. CAH contamination has not been detected in site soils (ES, 1994b); therefore, results are not reported in Table 2.3. The approximate extent of soil BTEX and TPH contamination and the locations of all soil samples collected at FT-1 are shown in Figure 2.9. Isoconcentration lines have not been added



LEGEND

- B-2 SOIL BOREHOLE (INSTALLED 1986)
- BH-2 SOIL BOREHOLE (INSTALLED 1988)
- 002 SOIL BOREHOLE (INSTALLED 1991)
- C VAPOR MONITORING POINT (VMP)
- ESTIMATED EXTENT OF BTEX AND TPH CONTAMINATION IN SOILS
- EXTENT OF WETLANDS
- CONFINED-SPACE FIRE TRAINING FACILITY

NOTE: WELLS MW-119, MW-121, MW-123, MW-124 AND MW-125 ARE LOCATED EAST OF THE SITE AND ARE NOT SHOWN HERE

FIGURE 2.9

APPROXIMATE EXTENT OF SOIL BTEX CONTAMINATION

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

95DN1423, 10/10/95 at 09:45

TABLE 2.3
SUMMARY OF SOIL ANALYTICAL DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Soil Borehole Identification	Sampling Date	Sample Depth (feet bgs)[b/]	Benzene (mg/kg)[c/]	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX (mg/kg)	TPH [a/] (mg/kg)	Source [d/]
B-1	1986	0.0-0.5	ND [e/]	ND	ND	ND	ND	730	1
B-1	1986	2.0-3.5	ND	ND	ND	ND	ND	ND	1
B-2	1986	0.0-0.5	ND	ND	ND	ND	ND	927	1
B-2	1986	0.5-2.0	ND	5.3	3.2	36.2	44.7	1660	1
B-3	1986	5.0-6.5	35.7	109.7	52.3	329.1	526.8	8350	1
B-3	1986	10.0-11.5	1	2.8	4.2	21.7	29.7	1160	1
BH-1	1988	4	ND	ND	ND	90	90	2000	1
BH-2	1988	4.5	ND	ND	ND	ND	ND	ND	1
BH-3	1988	4.5	ND	ND	ND	ND	ND	ND	1
BH-4	1988	4.8	ND	ND	ND	ND	ND	ND	1
BH-5	1988	5	ND	ND	ND	ND	ND	ND	1
MW-49	1988	8.5-9.0	ND	ND	ND	ND	ND	ND	1
MW-50	1988	3.5-4.0	ND	ND	ND	ND	ND	ND	1
MW-50	1988	8.0-8.5	ND	ND	ND	ND	ND	ND	1
MW-50	1988	13.0-13.5	ND	ND	ND	ND	ND	ND	1
MW-51	1988	3.0-3.5	ND	ND	ND	ND	ND	ND	1
MW-51	1988	3.5-4.0	ND	ND	ND	ND	ND	21	1
MW-51	1988	8.0-8.5	ND	ND	ND	ND	ND	ND	1
MW-52	1988	0.0-0.5	ND	ND	ND	ND	ND	ND	1
MW-52	1988	3.0-3.5	ND	ND	ND	ND	ND	ND	1
MW-52	1988	8.0-8.5	ND	ND	ND	ND	ND	ND	1
MW-52	1988	13.0-13.5	ND	ND	ND	ND	ND	ND	1
MW-53	1988	3.0-3.5	ND	ND	ND	ND	ND	ND	1
MW-53	1988	8.0-8.5	ND	ND	ND	ND	ND	ND	1
MW-53	1988	8.5-9.0	ND	ND	ND	ND	ND	ND	1
MW-53	1988	13.0-13.5	ND	ND	ND	ND	ND	ND	1

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TABLE 2.3 (Continued)
SUMMARY OF SOIL ANALYTICAL DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Soil Borehole Identification	Sampling Date	Sample Depth (feet bgs) [b/]	Benzene (mg/kg) [c/]	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX (mg/kg)	TPH [a/] (mg/kg)	Source [d/]
001	1991	4-6	ND	ND	ND	ND	ND	ND	1
001	1991	6-8	ND	ND	ND	ND	ND	ND	1
002	1991	2-4	ND	ND	ND	ND	ND	180	1
003	1991	2-4	ND	ND	18 J [f/]	130 J	148 J	6700	1
004	1991	4-6	ND	ND	ND	ND	ND	ND	1
005	1991	2-4	ND	ND	ND	ND	ND	4300	1
005	1991	6-8	ND	ND	ND	ND	ND	ND	1
006	1991	0-2	ND	ND	ND	ND	ND	ND	1
007	1991	0-2	ND	0.008 J	ND	ND	0.008 J	ND	1
007	1991	4-6	ND	ND	ND	ND	ND	ND	1
008	1991	2-4	ND	20 J	14 J	100 J	134 J	ND	1
009	1991	2-4	ND	ND	ND	ND	ND	62	1
009	1991	6-8	ND	ND	ND	2.8	2.8	ND	1
010	1991	2-4	14	170	61	110	355	7500	1
010	1991	4-6	ND	45	18	140	203	5500	1
011	1991	2-4	ND	ND	ND	ND	ND	ND	1
011	1991	4-6	ND	ND	ND	ND	ND	450	1
012	1991	2-4	ND	ND	ND	ND	ND	ND	1
013	1991	2-4	ND	ND	ND	ND	ND	25	1
013	1991	4-6	ND	ND	ND	ND	ND	37	1
014	1991	0-2	ND	ND	23	14	37	2900	1
014	1991	2-4	ND	ND	0.027 J	0.18 J	0.207 J	1600	1
015	1991	0-2	ND	ND	ND	3.9 J	3.9 J	890 J	1
015	1991	2-4	ND	ND	2.6 J	15 J	17.6 J	4500	1
016	1991	0-6	ND	ND	ND	ND	ND	ND	1
017	1991	0-6	ND	ND	ND	ND	ND	ND	1

022/722450/FCWP/18.XLS

TABLE 2.3 (Concluded)
SUMMARY OF SOIL ANALYTICAL DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Soil Borehole Identification	Sampling Date	Sample Depth (feet bgs)[b/]	Benzene (mg/kg)[c/]	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Total BTEX (mg/kg)	TPH [a/] (mg/kg)	Source [d/]
018	1991	2-4	ND	ND	ND	ND	ND	ND	1
018	1991	4-6	ND	ND	11	69	80	3200	1
019	1991	0-7	ND	48	29 J	200 J	277 J	3500	1
020	1991	0-10	ND	ND	ND	ND	ND	48	1
VMPA	1994	2	ND	0.015	ND	ND	0.015	110	2
VMPA	1994	4	ND	ND	ND	ND	ND	2000	2
VMPB	1994	2	ND	0.086	ND	ND	0.086	25	2
VMPB	1994	4	ND	0.5	ND	0.023	0.523	1800	2
VMPC	1994	2	ND	0.068	ND	1.9	1.968	30	2
VMPC	1994	4	0.096	0.15	0.087	0.61	0.943	4900	2

Notes:
[a/] TPH = total petroleum hydrocarbons.
[b/] feet bgs = feet below ground surface.
[c/] mg/kg = milligrams per kilogram.
[d/] Sources:
1. HNUS, 1993
2. ES, 1994b.
[e/] ND = Not detected.
[f/] J = estimated value.

022/722450/FCWP/18.XLS

to Figure 2.9 because active *in situ* remedial efforts are currently treating these soils, and current soil data are not available.

The greatest BTEX and TPH contamination was detected in soil samples collected from the burn pit and the area south of the burn pit (Table 2.3). At FT-1, the highest soil concentrations of BTEX and TPH were detected in 1986 in borehole B-3 installed in the southern portion of the burn pit (Figure 2.9). The highest BTEX concentrations in the 1990 soil sampling effort were detected in the 4- to 6-foot bgs sample collected from borehole 010, south of the burn pit (HNUS, 1993a). BTEX and TPH also were detected in soil samples collected from the VMPs installed during the bioventing pilot test and located approximately 15 feet south of the burn pit (ES, 1994b).

A secondary region of soil contamination has been identified east of the burn pit. Samples collected in 1986 from soil boreholes B-1 and B-2, located approximately 200 and 250 feet east of the burn pit, respectively, had elevated BTEX concentrations (Table 2.3). A soil sample collected in 1988 from soil borehole BH-1, located approximately 400 feet east of the burn pit, also had elevated concentrations of soil contamination. Each of these boreholes is located immediately downstream and downgradient from the effluent outfall from the oil/water separator (Figure 2.9). Additionally, BTEX and TPH were detected in one composite sample collected from 019 along the eastern edge of the burn pit upgradient from the oil/water separator and in samples from 101 southwest of the pit, and 014 and 015 to the east along the ditch. In summary soil contamination at FT-1 has been identified along the southern and eastern edges of the burn pit and east of the oil/water separator.

2.1.3.2 Groundwater Sampling and Analytical Results

A total of 40 monitoring wells have been installed in the vicinity of FT-1. In 1988, five monitoring wells (MW-49, MW-50, MW-51, MW-52, and MW-53) were installed at FT-1. In 1991, 16 additional monitoring wells (MW-148 through MW-163) were installed at FT-1 (HNUS, 1993a). Although numerical well numbers suggest the sequence of installation of monitoring wells at FT-1, exact dates of installation and other construction details for the remaining 17 wells were not presented in previous reports reviewed during the development of this work plan.

Groundwater quality data reviewed during development of this work plan were collected during sampling events performed at FT-1 in 1986, 1987, 1989 (two sampling events), 1990, 1991 (three sampling events), 1993, and 1995. Concentrations of VOCs and TPH were measured in groundwater samples collected during all sampling events. Other analytical data collected during previous sampling events including total dissolved solids, total suspended solids, chemical oxygen demand, biological oxygen demand, total organic carbon (TOC), ammonia, common anions, and nitrate/nitrite data, will be useful for evaluating intrinsic remediation at FT-1, and efforts will be made to obtain this data (HNUS, 1993a). However, only analytical data for BTEX, TPH, TCE, and TCE breakdown products were available for inclusion in this work plan. Concentrations of dissolved BTEX, TPH, TCE, and TCE breakdown products measured in groundwater samples collected during previous investigations are summarized in Table 2.4. Benzene and total BTEX concentrations detected in

TABLE 2.4
SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Date (month/year)	Benzene (µg/L) [c]	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX[a] (µg/L)	TPH[b] (mg/L) [b]	TCE[c] (µg/L)	*cis*-1,2-DCE[d] (µg/L)	*trans*-1,2-DCE (µg/L)	Vinyl Chloride (µg/L)	Source [g]
MW-1	11/86	ND [h]	ND	ND	0.6 J	0.6 J[i]	ND	ND	ND	2.9 J	ND	1
	11/87	ND	ND	ND	ND	ND	ND	2.3 J	ND	6.5	ND	1
	4/89	43	ND	75	87	205	0.3 J	2.1 J	ND	17	ND	1
	7/89	ND	ND	ND	ND	ND	ND	1.0 J	ND	1.0 J	ND	1
	4/91	9	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/95	1.5	1.6	ND	ND	3.1	NA [j]	ND	3.6	ND	ND	2
MW-2	11/86	ND	ND	ND	ND	ND	ND	ND	ND	73.1	ND	1
	11/87	ND	ND	ND	ND	ND	ND	16	ND	46	ND	1
	4/89	ND	ND	ND	ND	ND	ND	29	ND	360	ND	1
	7/89	ND	ND	ND	ND	ND	ND	12	ND	38	ND	1
	4/91	ND	ND	ND	ND	ND	ND	12	ND	97	ND	1
	11/91	ND	ND	ND	ND	ND	ND	3	ND	9	ND	1
	4/95	ND	1.4	2.7	7.7	11.8	NA	6.1	68	34	ND	2
MW-3	11/86	1.5 J	0.4 J	1.4	8.1	11.4 J	ND	ND	ND	ND	35.9	1
	11/87	ND	3 J	ND	27	30 J	ND	ND	ND	ND	ND	1
	4/89	79	ND	68	180	327	ND	ND	ND	ND	16	1
	7/89	170	ND	100	250	520	ND	ND	ND	ND	ND	1
	4/91	66	ND	45	110	221	ND	ND	ND	ND	ND	1
	11/91	320	ND	220	780	1320	ND	ND	ND	ND	ND	1
	4/95	220	9.2	150	539.2	918.4	NA	ND	2.1	1.5	43	1
MW-4	11/86	ND	ND	ND	ND	ND	ND	0.54 J	ND	ND	ND	1
	11/87	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/89	ND	ND	ND	ND	ND	0.3 J	ND	ND	ND	ND	1
	7/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1

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TABLE 2.4 (Continued)
SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Date (month/year)	Benzene (µg/L) [e]	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX[a] (µg/L)	TPH[b] (mg/L) [b]	TCE[c] (µg/L)	*cis*-1,2-DCE[d] (µg/L)	*trans*-1,2-DCE (µg/L)	Vinyl Chloride (µg/L)	Source [g]
MW-4 (cont.)	4/95	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	2
MW-6	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-13	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-50	4/89	ND	ND	ND	ND	ND	ND	4.2 J	ND	4.0 J	ND	1
	7/89	ND	ND	ND	ND	ND	ND	5	ND	0.8	ND	1
	6/90	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	8/90	ND	ND	ND	ND	ND	ND	2 J	ND	4.0 J	ND	1
	11/91	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	1
	4/95	ND	ND	ND	ND	ND	NA	1.8	ND	ND	ND	2
MW-51	4/89	ND	ND	ND	ND	ND	ND	5.7	ND	ND	ND	1
	7/89	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	1
	6/90	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	8/90	ND	ND	ND	ND	ND	ND	5	4.0 J	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	1
MW-52	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-53	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-61	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-98	2/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1

022/722450/FCWP/19.XLS

TABLE 2.4 (Continued)
SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Date (month/year)	Benzene (µg/L) [c]	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX[a] (µg/L)	TPH[b] (mg/L) [b]	TCE[c] (µg/L)	*cis*-1,2-DCE[d] (µg/L)	*trans*-1,2-DCE (µg/L)	Vinyl Chloride (µg/L)	Source[g]
MW-100	2/91	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	1
	4/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	9	1
	11/91	ND	ND	ND	ND	ND	ND	0.7	ND	ND	ND	1
	4/95	ND	ND	ND	ND	ND	NA	ND	ND	ND	4	2
MW-104	2/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	1
MW-121	4/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-123	4/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-124	4/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-125	4/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	11/91	ND	ND	ND	ND	ND	ND	0.6	ND	ND	ND	1
MW-148	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-149	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-150	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-151	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/95	2.1	1.6	ND	ND	3.7	NA	ND	ND	ND	1	2

022/722450/FCWP/19.XLS

TABLE 2.4 (Continued)
SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Date (month/year)	Benzene (µg/L) [e]	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX[a] (µg/L)	TPH[b] (mg/L) [b]	TCE[c] (µg/L)	*cis*-1,2-DCE[d] (µg/L)	*trans*-1,2-DCE (µg/L)	Vinyl Chloride (µg/L)	Source [g]
MW-152	11/91	56	10	45	120	231	ND	ND	ND	ND	ND	1
	4/95	150	7	170	585	912	NA	ND	ND	ND	11	2
MW-153	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/95	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	2
MW-154	11/91	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	1
	4/95	ND	43	ND	6.1	49.1	NA	ND	ND	ND	ND	2
MW-155	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/95	1.5	2.4	1.8	6.6	12.3	NA	ND	ND	ND	ND	2
MW-156	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
	4/95	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	2
MW-157	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-158	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-159	11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
MW-225	10/93	ND	NA	NA	NA	NA	ND	ND	NA	NA	NA	3
MW-226	10/93	ND	NA	NA	NA	NA	ND	ND	NA	NA	NA	3
MW-227	10/93	ND	NA	NA	NA	NA	ND	ND	NA	NA	NA	3
RW-12	1/92	ND	ND	ND	ND	ND	ND	0.7	ND	ND	ND	1
RW-15	1/92	ND	ND	ND	ND	ND	ND	0.2	ND	ND	ND	1
RW-16	1/92	ND	ND	ND	ND	ND	ND	0.3	ND	ND	ND	1

022/722450/FCWP/19.XLS

TABLE 2.4 (Concluded)
SUMMARY OF GROUNDWATER ANALYTICAL DATA
SITE FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

Location	Sampling Date (month/year)	Benzene (µg/L) [e]	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX[a] (µg/L)	TPH[b] (mg/L) [f]	TCE[c] (µg/L)	*cis*-1,2-DCE[d] (µg/L)	*trans*-1,2-DCE (µg/L)	Vinyl Chloride (µg/L)	Source [g]
RW-20	1/92	ND	ND	ND	ND	ND	ND	0.5	ND	ND	ND	1
RW-21	1/92	ND	ND	ND	ND	ND	ND	0.4	ND	ND	ND	1
RW-23	1/92	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	1
RW-24	1/92	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	1
RW-45	1/92	ND	ND	ND	ND	ND	ND	0.3	ND	ND	ND	1

[a] BTEX = benzene, toluene, ethylbenzene, xylenes.

[b] TPH = total petroleum hydrocarbons.

[c] TCE = trichloroethene.

[d] DCE = dichloroethene.

[e] µg/L = micrograms per liter.

[f] mg/L = milligrams per liter.

[g] Sources:
1. HNUS, 1993.
2. ES&T AND MWA, 1995.
3. ES, 1994a

[h] ND = not detected.

[i] NA = not analyzed.

[j] J = estimated value.

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groundwater samples collected during the most recent 1995 sampling effort are presented in Figure 2.10. TCE and TCE-breakdown product detected during the 1995 sampling effort are presented in Figure 2.11.

Dissolved BTEX have repeatedly been identified in groundwater samples from shallow wells in the unconsolidated deposits southeast of the burn pit. Dissolved BTEX concentrations also have been detected at low concentrations in some bedrock wells southeast of the burn pit. Dissolved BTEX have not been detected in other regions of the site. Neither shallow nor bedrock wells are located within 100 feet of the burn pit. Comparison of BTEX groundwater data collected at FT-1 suggests that BTEX concentrations downgradient of the burn pit have increased with time. This trend is observed in groundwater results from monitoring wells MW-3 and MW-152. In 1995, a slight decline in the BTEX concentrations was observed at MW-3, the well closer to the burn pit. This decline may be the direct result of on-going bioventing and air sparging pilot tests, which were initiated in 1994, or it may be a statistical anomaly. Additional dissolved BTEX data are needed to fully characterize the areal extent of dissolved BTEX contamination and in order to more thoroughly understand the dynamics of the dissolved BTEX plume downgradient from the burn pit.

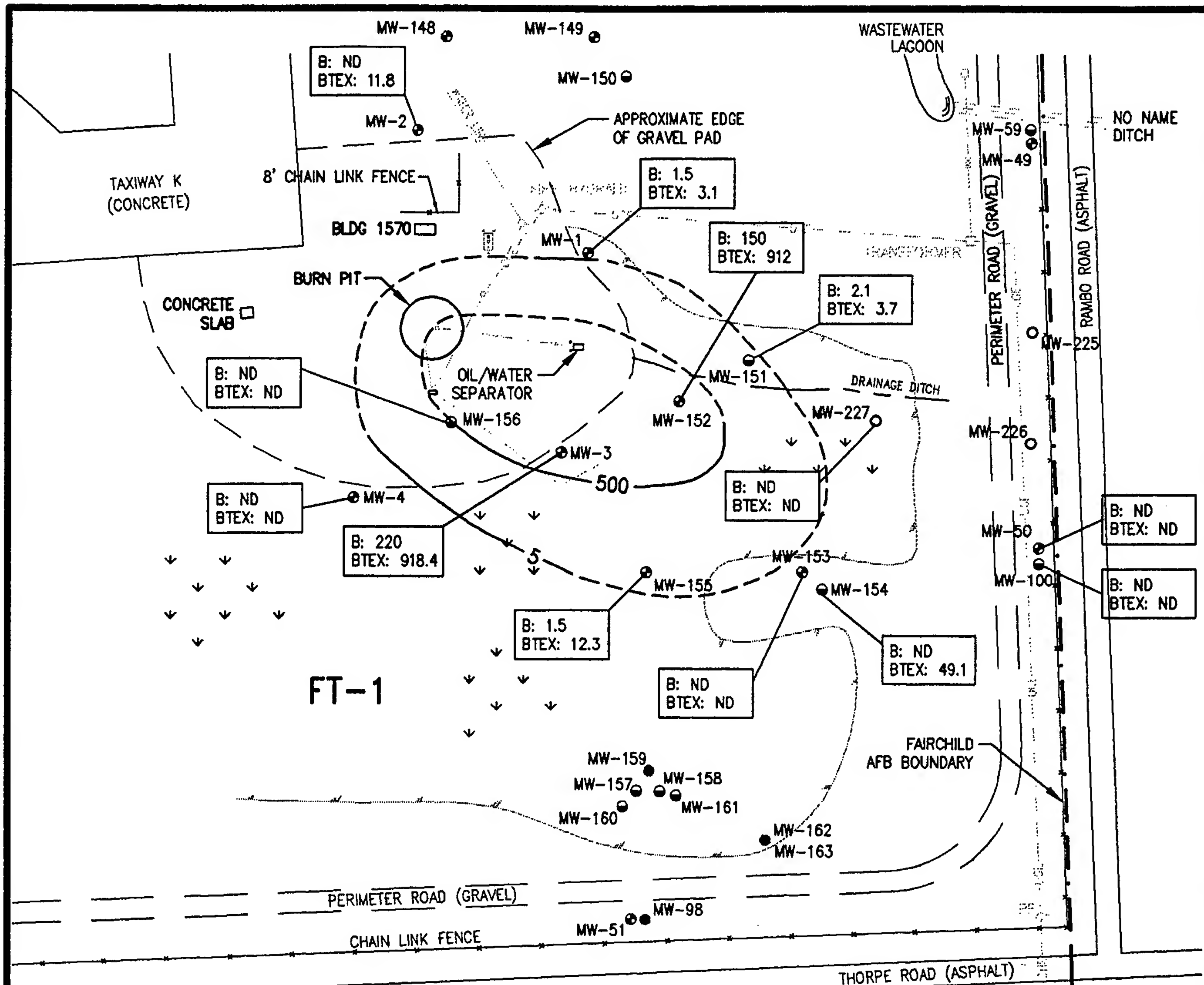
Low concentrations of TCE and related breakdown products have been detected consistently in three areas at the site: near the burn pit, along the eastern boundary of the Base near MW-50 and MW-100, and near the southern boundary of the Base near MW-51 (Figure 2.11 and Table 2.4). Concentrations of TCE and breakdown products measured throughout the site are relatively constant and low, equal to or less than 5 µg/L. In the other regions of the site, the concentrations of TCE and breakdown products appear to be decreasing over time. TCE contamination also has been detected up to 1 mile downgradient from the site in surrounding residential wells, but all detected concentrations of TCE in groundwater samples collected from residential wells located immediately east-southeast of the site are below 1 µg/L, as shown on Figure 2.12. (HNUS, 1993a).

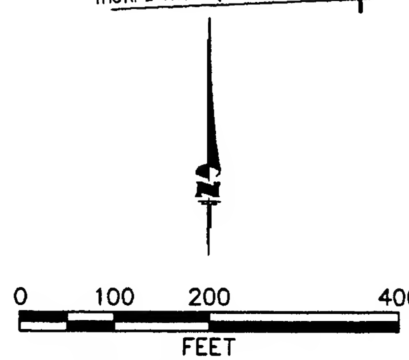
2.2 DEVELOPMENT OF CONCEPTUAL SITE MODEL

A CSM is a three-dimensional representation of a site's hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. A CSM is developed to provide an understanding of the mechanisms controlling contaminant fate and transport and to identify additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, and contaminant migration pathways. The model also provides a foundation for formulating decisions regarding additional data collection activities and potential remedial actions. The CSM for FT-1 will be used to aid in selecting additional data collection points and to identify appropriate data needs for modeling and hydrocarbon degradation using groundwater flow and solute transport models.

Successful conceptual model development involves:

- Defining the problem to be solved;





LEGEND

- SHALLOW MONITORING WELL
- SHALLOW BEDROCK MONITORING WELL
- DEEP BEDROCK MONITORING WELL
- MONITORING WELL (SCREENED INTERVAL UNKNOWN)
- 100 — LINE OF ESTIMATED EQUAL BTEX CONCENTRATIONS (DASHED WHERE INFERRED)
- B: 1.5 — DISSOLVED BENZENE: MEASURED CONCENTRATION (μg/L)
- BTEX: 3.1 — DISSOLVED TOTAL BTEX: MEASURED CONCENTRATION (μg/L)
- ND — ANALYTE NOT DETECTED ABOVE METHOD DETECTION LIMIT
- EXTENT OF WETLANDS
- CONFINED-SPACE FIRE TRAINING FACILITY

NOTES: WELLS MW-119, MW-121, MW-123, MW-124 AND MW-125 ARE LOCATED EAST OF THE SITE AND ARE NOT SHOWN HERE

ISOCONCENTRATION LINES ARE PLOTTED FOR BTEX CONCENTRATIONS MEASURED IN UNCONSOLIDATED WELLS ONLY

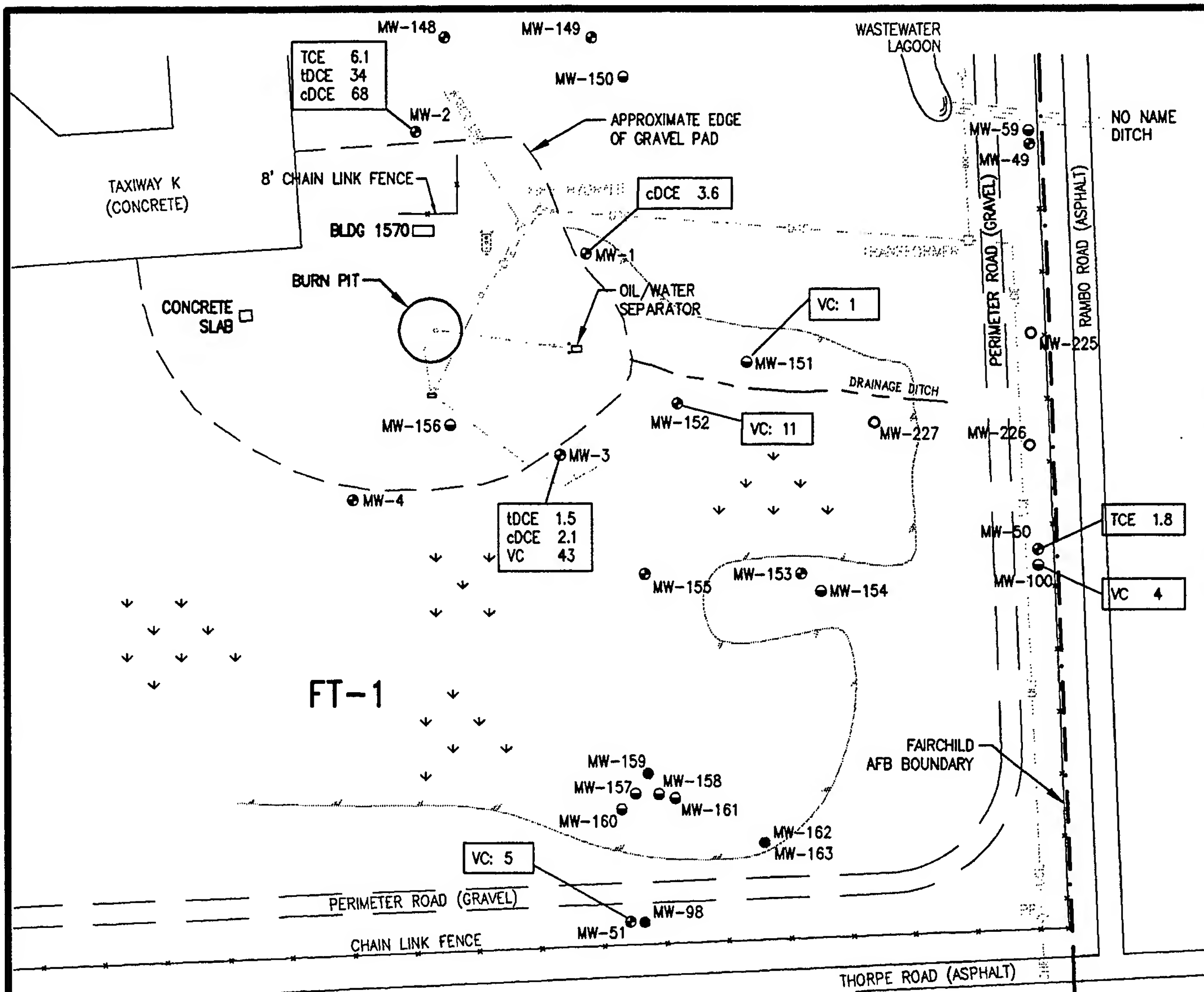
FIGURE 2.10

EXTENT OF DISSOLVED BENZENE AND TOTAL BTEX CONTAMINATION (APRIL 1995)

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

95DN1428, 10/10/95 at 09:10



LEGEND

- SHALLOW MONITORING WELL
- SHALLOW BEDROCK MONITORING WELL
- DEEP BEDROCK MONITORING WELL
- MONITORING WELL (SCREENED INTERVAL UNKNOWN)

TCE TRICHLOROETHENE (µg/L)
cDCE cis-1,2-DICHLOROETHENE (µg/L)
tDCE trans-1,2-DICHLOROETHENE (µg/L)
VC VINYL CHLORIDE (µg/L)

EXTENT OF WETLANDS

CONFINED-SPACE FIRE TRAINING FACILITY

NOTE: WELLS MW-119, MW-121, MW-123, MW-124 AND MW-125 ARE LOCATED EAST OF THE SITE AND ARE NOT SHOWN HERE

N

0 100 200 400
FEET

FIGURE 2.11

DETECTED CONCENTRATION OF DISSOLVED CAH CONTAMINATION (APRIL 1995)

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

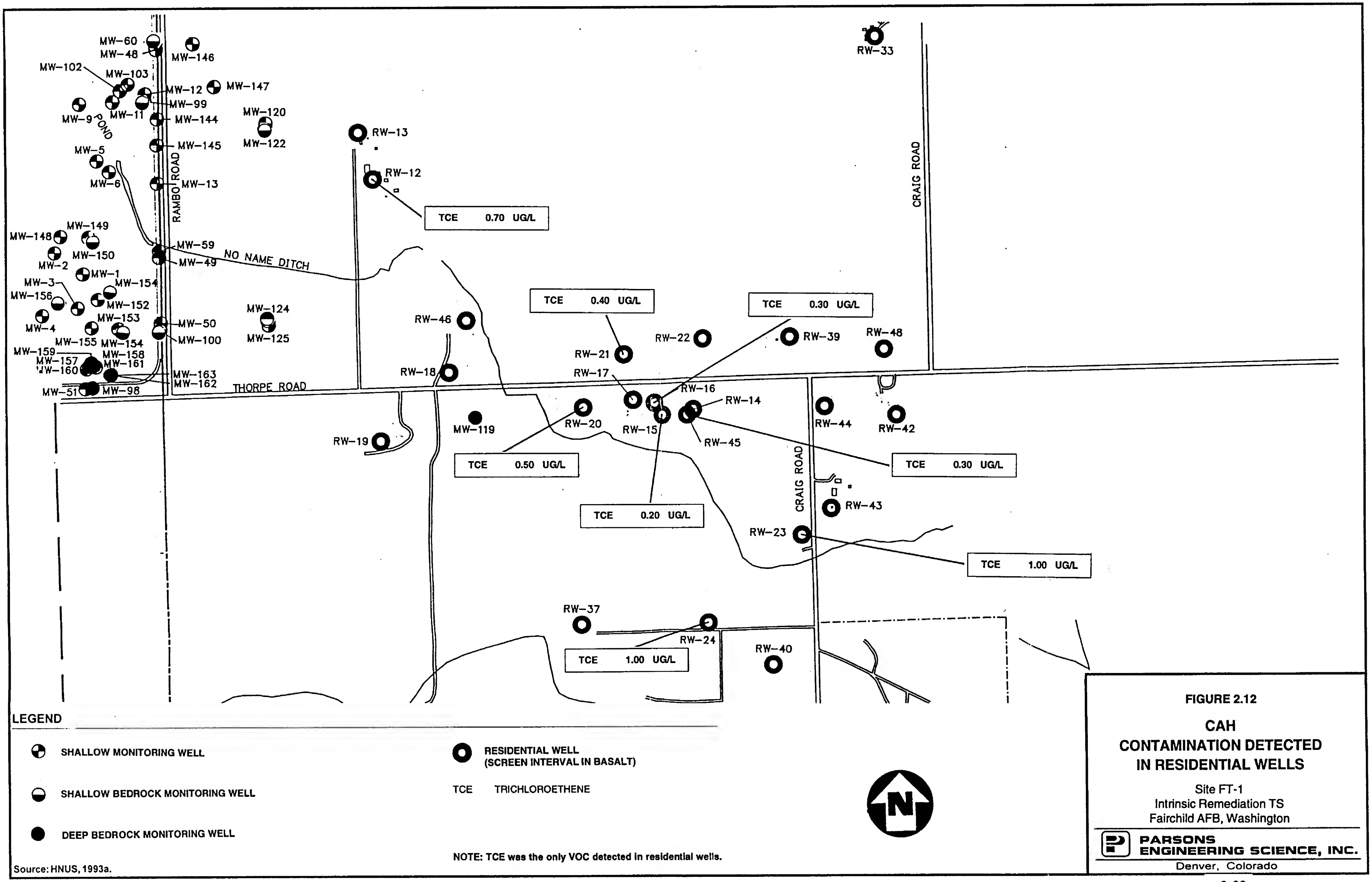


FIGURE 2.12

CAH
CONTAMINATION DETECTED
IN RESIDENTIAL WELLS

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS
ENGINEERING SCIENCE, INC.
Denver, Colorado

- Integrating available data, including
  - Local geologic and topographic data,
  - Hydraulic data,
  - Site stratigraphic data,
  - Contaminant concentration and distribution data;
- Evaluating contaminant fate and transport characteristics;
- Identifying contaminant migration pathways;
- Identifying potential receptors and receptor exposure points; and
- Determining additional data requirements.

2.2.1 Intrinsic Remediation and Groundwater Flow and Solute Transport Models

After a site has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and whether any pathway for exposure of human or ecological receptors to site contaminants is complete or may be completed in the future. Groundwater flow and solute transport models have proven useful for predicting BTEX plume migration and contaminant attenuation by natural biodegradation. Analytical solute transport models and the Bioplume II numerical model (Rifai *et al.*, 1988) can be used to evaluate critical groundwater fate and transport processes that may be involved in some of the migration pathways to human and ecological receptors. Quantitative fate and transport analyses can be used to determine what level and extent of remediation is required. Where remedial systems are in place or are in development (such as at FT-1), assumptions on the effectiveness of these systems at reducing source and mass, reducing dissolved contaminant concentrations in the groundwater, or increasing the availability of electron acceptors can also be included in the models.

An accurate estimate of the potential for natural biodegradation of BTEX and CAH compounds in groundwater is important to consider when determining whether fuel hydrocarbon or chlorinated solvent contamination presents a substantial threat to human health or the environment, and when designing a cost-effective remedial system capable of eliminating or abating these threats. Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons (Lee, 1988). This process occurs naturally when sufficient oxygen (or other electron acceptors) and nutrients are available in the groundwater. The rate of natural biodegradation is generally limited by the lack of oxygen (or other electron acceptors) rather than by the lack of nutrients such as nitrogen or phosphorus. The supply of oxygen to unsaturated soil is constantly renewed by the vertical diffusion from the atmosphere. The natural biodegradation of CAHs occurs through the process of cometabolism in which enzymes or cofactors produced during the degradation of organic materials in the aquifer serve as catalysts in the degradation of CAHs. Norris *et al.* (1994) documents theory and research related to the cometabolism of CAH compounds.

2.2.2 Biodegradation of Dissolved BTEX Contamination

The positive effect of natural attenuation processes (e.g., advection, dispersion, sorption, and biodegradation) on reducing the actual mass of contamination dissolved in groundwater has been termed intrinsic remediation. Intrinsic remediation is advantageous for the following reasons:

- Contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and water), not just transferred to another phase or location within the environment;

- Current pump-and-treat technologies are energy-intensive and generally not as effective in reducing residual contamination;

- The process is nonintrusive and allows continuing use of infrastructure during remediation;

- Current engineered remedial technologies may pose a greater risk to potential receptors than intrinsic remediation because contaminants may be transferred into the atmosphere during remediation activities; and

- Intrinsic remediation is far less costly than conventional, engineered remedial technologies.

To estimate the impact of natural attenuation on the fate and transport of BTEX compounds dissolved in groundwater at a site, two important lines of evidence must be demonstrated (Wiedemeier *et al.*, 1995). The first is a documented loss of contaminants at the field scale. To supplement evidence provided by historical site data, dissolved concentrations of biologically recalcitrant tracers found in most fuel contamination are used in conjunction with aquifer hydrogeologic parameters, such as groundwater seepage velocity and dilution, to demonstrate that a reduction in contaminant mass is occurring at the site. The second line of evidence involves the use of chemical analytical data in mass balance calculations to show that areas with BTEX contamination can be correlated to areas with depleted electron acceptor (e.g., oxygen, nitrate, and sulfate) concentrations and increases in metabolic fuel degradation byproduct concentrations (e.g., methane and ferrous iron). With this site-specific information, groundwater flow and solute transport models can be used to simulate the fate and transport of dissolved BTEX compounds under the influence of natural attenuation.

To estimate the impact of cometabolism on the fate and transport of CAH compounds dissolved in groundwater at a site, two lines of evidence analogous to the BTEX evidence will be investigated. Once again, the first is documented loss of contaminants at the field scale and involves interpretations of historical data and the use of conservative tracers. The second line of evidence involves the use of chemical analytical data to demonstrate the transformation of the source solvent to daughter products and subsequent degradation to innocuous end products.

Analytical and numerical models are available for modeling the fate and transport of fuel hydrocarbons under the influence of advection, dispersion, sorption, and natural

aerobic and anaerobic biodegradation. Analytical models may be used in conjunction with the Bioplume II numerical model, as appropriate or to simulate fate and transport of CAH compounds. The Bioplume II numerical model is based upon the USGS two-dimensional (2-D) solute transport model, which has been modified to include a biodegradation component that is activated by a superimposed plume of dissolved oxygen. Bioplume II solves the USGS 2-D solute equation twice, once for hydrocarbon concentrations in the groundwater and once for a dissolved oxygen plume. The two plumes are then combined using superimposition at every particle move to simulate biological reactions between fuel products and oxygen. As appropriate, biodegradation of contaminants by anaerobic processes is simulated using a first-order anaerobic decay rate.

The analytical solute transport models are derived from advection-dispersion equations given by Wexler (1992) and van Genuchten and Alves (1982). These models provide exact, closed-form solutions and are appropriately used for relatively simple hydrogeologic systems that are homogeneous and isotropic. Each model is capable of simulating advection, dispersion, sorption, and biodegradation (or any first-order decay process). These models can simulate continuous or decaying sources. A continuous-source model is useful for determination of the worst-case distribution of the dissolved contaminant plume. A decaying-source model is useful for simulating source removal scenarios, including natural weathering processes and engineered solutions.

2.2.3 Initial Conceptual Site Model

Site FT-1 geologic data were previously integrated to produce two geologic cross-sections of the site. Cross sections A - A' and B - B' (Figures 2.6 and 2.7) show the dominant hydrostratigraphic units present at the site and the elevation of the water table. Figure 2.8 is a groundwater surface map prepared using October 1992 groundwater elevation data (HNUS, 1993a).

The surface of the groundwater table is present at approximately 4 to 6 feet bgs in unconsolidated deposits which are primarily sand and gravel glacial deposits in the vicinity of the site. Groundwater also occurs in shallow bedrock, which is present at 9 to 30 feet bgs. Groundwater flow in the unconsolidated material is east-southeast, with an average gradient of 0.002 ft/ft that steepens near the source area and just beyond the Base boundary to approximately 0.007 ft/ft. On the basis of the available data, Parsons ES will model the site as an unconfined, fine- to coarse-grained sand and gravel aquifer. This CSM will be modified as necessary as additional site hydrogeologic data become available.

Mobile LNAPL has not been identified at FT-1. However, if it is encountered, it may be necessary to use the fuel/water partitioning models of Bruce *et al.* (1991) or Cline *et al.* (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into the groundwater. In order to use one of these models, samples of product will be collected and analyzed for mass fraction of BTEX compounds. If LNAPL is present, Parsons ES will attempt to collect groundwater samples from immediately below the LNAPL layer, if possible.

The site-specific remedial goal for FT-1, as specified in the ROD is to remediate groundwater until benzene concentrations below 5 µg/L are attained across the site (HNUS, 1993b). However, the synergistic effects of all of the BTEX compounds on attenuation rates make site data on all of the BTEX compounds important. Additionally, TCE and the associated breakdown products have been indicated to be chemicals of potential concern at the site (HNUS, 1993b). All of the BTEX compounds, TCE, and the daughter products of TCE (CDCE, tDCE, and VC) will be the focus of this intrinsic remediation study because of their regulatory importance. Analytical groundwater flow and solute transport models will be used to simulate the migration and degradation of the chemicals of concern at FT-1 and will be used to predict the concentration and extent of the groundwater contaminant plume over time.

The BTEX compounds at the site are expected to leach from contaminated soil, which is known to contain fuel residuals (Table 2.3), into the groundwater and migrate with the dissolved CAH compounds downgradient as a dissolved contaminant plume. It is suspected that CAH compounds may be present in the groundwater as the result of an upgradient source because they have been detected in groundwater samples from upgradient wells and have not been detected in site soil samples. In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, and adsorption), these dissolved contaminants will likely be removed from the groundwater system by naturally occurring destructive attenuation mechanisms, such as biodegradation or biologically induced cometabolism. The effects of these transport and fate processes on the dissolved groundwater plume will be investigated using the quantitative groundwater analytical data and groundwater flow and solute transport models. Data collection and analysis requirements are discussed in Section 3 of this work plan.

2.2.4 Potential Groundwater Pathways and Receptors

Potential preferential contaminant migration pathways such as groundwater discharge points and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. The primary potential migration path for BTEX contamination at FT-1 results from the leaching of residual fuels from contaminated site soils into the groundwater. Dissolved concentrations of BTEX and CAHs can be transported with migrating groundwater to potential receptors, who could be exposed via ingestion or incidental contact. There are residential water wells located within one-half mile downgradient from the site. Base drinking water does not come from wells located near or downgradient from FT-1.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the TS and to demonstrate that intrinsic remediation of fuel-related contaminants and chlorinated solvents is occurring, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the TS.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the groundwater surface in site monitoring wells;
- Locations of potential groundwater preferential flow pathways and recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimate of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Groundwater temperature; and
- Determination of extent and thickness of mobile and residual LNAPL (if present).

Chemical hydrogeologic characteristics to be determined include:

- Dissolved oxygen concentrations;
- Specific conductance;
- pH;
- Chemical analysis of any mobile LNAPL (if present) to determine mass fraction of BTEX; and
- Additional chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

TABLE 3.1
ANALYTICAL PROTOCOL FOR GROUNDWATER, SOIL, AND PRODUCT SAMPLES
FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

MATRIX Analyte	METHOD	FIELD (F) OR FIXED-BASE LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH Method 8008	F
Ferrous Iron (Fe^{2+})	Colorimetric, HACH Method 8146	F
Ferric Iron (Fe^{3+})	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034	F
Sulfate	Colorimetric, HACH Method 8051	F
Nitrate	Titrimetric, HACH Method 8039	F
Nitrite	Titrimetric, HACH Method 8507	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	Direct reading meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1, direct reading meter	F
Carbon Dioxide	Titrimetric, HACH Method 1436-01	F
Alkalinity (Carbonate [CO_3^{2-}]	Titrimetric, HACH Method 8221	F
and Bicarbonate [HCO3-])	EPA method 310.1	L
Nitrate + Nitrite	EPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane, Ethene	RSKSOP-147	L
Dissolved Organic Carbon	RSKSOP-102	L
Aromatic Hydrocarbons	RSKSOP-133	L
Fuel Carbon	RSKSOP-133	L
Chlorinated Solvents	RSKSOP-146	
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	RSKSOP-124, modified	L
Total Hydrocarbons	RSKSOP-174	L
Chlorinated Solvents	RSKSOP-146	
FREE PRODUCT		
BTEX Mass Fraction	GC/MS, Direct Injection	L

In order to obtain these data, soil, groundwater, and, if present, free product samples will be collected and analyzed. The following sections describe the procedures that will be followed when collecting additional site-specific data. Soil sampling and monitoring point installation will be accomplished using the Geoprobe® system as described in Sections 3.1 and 3.2. Soil core sample collection procedures are described in Section 3.1. Monitoring point installation procedures are described in Section 3.2. Groundwater sampling procedures for monitoring wells and newly installed groundwater monitoring points are described in Section 3.3. Measurement procedures for aquifer parameters (e.g., hydraulic conductivity) are described in Section 3.4.

3.1 SOIL SAMPLING

The following sections describe sampling locations, sample collection techniques, equipment decontamination procedures, site restoration, and management of investigation-derived waste materials.

3.1.1 Soil Sample Locations and Required Analyses

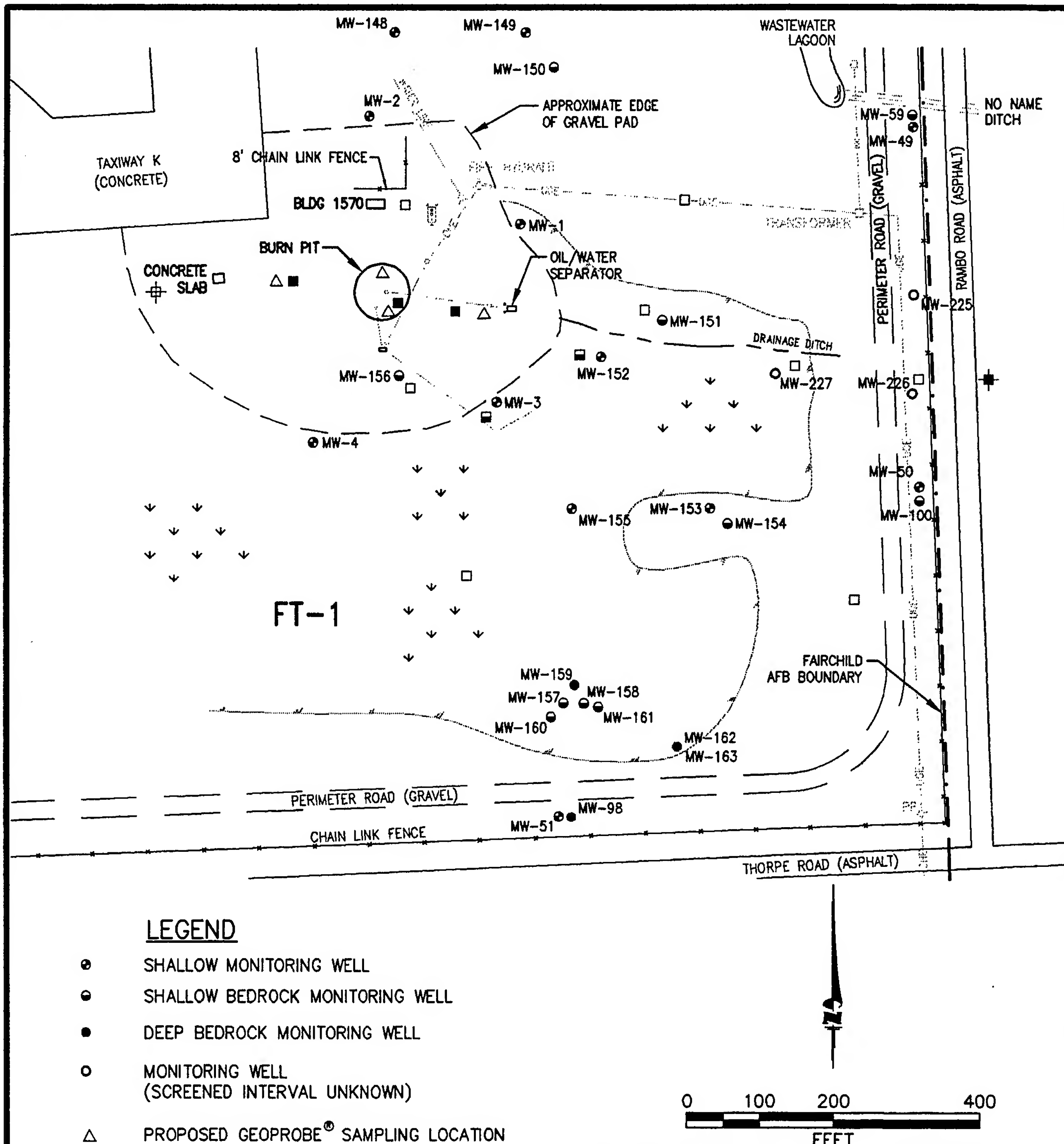
Soil samples will be collected at all Geoprobe® and monitoring point installation locations. Figure 3.1 identifies four proposed locations for soil sample collection at FT-1. Table 3.1 presents an analytical protocol for soil samples, and Appendix A contains detailed information on the analyses and methods to be used during this sampling effort.

A minimum of two samples will be collected from each Geoprobe® hole location. One sample will be taken at the water table, and one will be taken at the depth of maximum BTEX contamination as determined by soil headspace screening. Sampling locations include the suspected source areas on the northern and southern edges of the burn pit, upgradient from the burn pit mid way between the burn pit and the concrete slab, and 150 feet downgradient from the burn pit just west of the oil/water separator. Additional samples will be collected at the discretion of the Parsons ES field scientist.

A portion of each sample will be used to measure soil headspace, and another portion of selected samples will be delivered to the USEPA mobile laboratory for analytical analysis. Each laboratory soil sample will be placed in an analyte-appropriate sample container and hand-delivered to USEPA field personnel for analysis of total hydrocarbons, aromatic hydrocarbons, and moisture content using the procedures presented in Table 3.1. In addition, at least two samples will be analyzed for TOC from locations upgradient, crossgradient, or far downgradient from the contaminant source. Each headspace screening sample will be placed in a sealed plastic bag or mason jar and allowed to sit for at least 5 minutes. VOCs in soil headspace will then be determined using an organic vapor meter (OVM), and the results will be recorded in the field records by the Parsons ES field scientist.

3.1.2 Sample Collection Using the Geoprobe® System

Soil samples will be collected using a Geoprobe® system, a hydraulically powered percussion/probing machine capable of advancing sampling tools through



LEGEND

- SHALLOW MONITORING WELL
- SHALLOW BEDROCK MONITORING WELL
- DEEP BEDROCK MONITORING WELL
- MONITORING WELL (SCREENED INTERVAL UNKNOWN)
- PROPOSED GEOPROBE® SAMPLING LOCATION
- PROPOSED SHALLOW MONITORING POINT LOCATION
- PROPOSED DEEP MONITORING POINT LOCATION
- PROPOSED MONITORING POINT CLUSTER LOCATION
- OPTIONAL MONITORING POINT LOCATION
- OPTIONAL MONITORING POINT CLUSTER LOCATION
- EXTENT OF WETLANDS
- CONFINED-SPACE FIRE TRAINING FACILITY

FIGURE 3.1

PROPOSED SOIL SAMPLING AND MONITORING POINT LOCATIONS

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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Denver, Colorado

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unconsolidated soils. This system allows the rapid collection of soil, soil gas, and groundwater samples at shallow depths while minimizing the generation of investigation-derived waste materials. Figure 3.2 is a diagram of the Geoprobe® system.

Soil samples will be collected using a probe-drive sampler. The probe-drive sampler serves as both the driving point and the sample collection device and is attached to the leading end of the probe rods. To collect a soil sample, the sampler is pushed or driven to the desired sampling depth, the drive point is retracted to open the sampling barrel, and the sampler is subsequently pushed into the undisturbed soils. The soil cores are retained within brass, stainless steel, or clear acetate liners inside the sampling barrel. The probe rods are then retracted, bringing the sampling device to the surface. The soil sample can then be extruded from the liners for lithologic logging, or the liners can be capped, and undisturbed samples can be submitted to the analytical laboratory for testing.

If the probe-drive sampling techniques described above are inappropriate, inadequate, or unable to efficiently provide sufficient soil samples for the characterization of the site, continuous soil samples will be obtained from conventional soil boreholes using a hand auger or similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic log form is presented in Figure 3.3. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

Base personnel will be responsible for identifying the location of all utility lines, USTs, fuel lines, or any other underground infrastructure prior to any sampling activities. All necessary digging permits will be obtained by Base personnel prior to mobilizing to the field. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed locations. Parsons ES will be responsible for providing trained operators for the Geoprobe®.

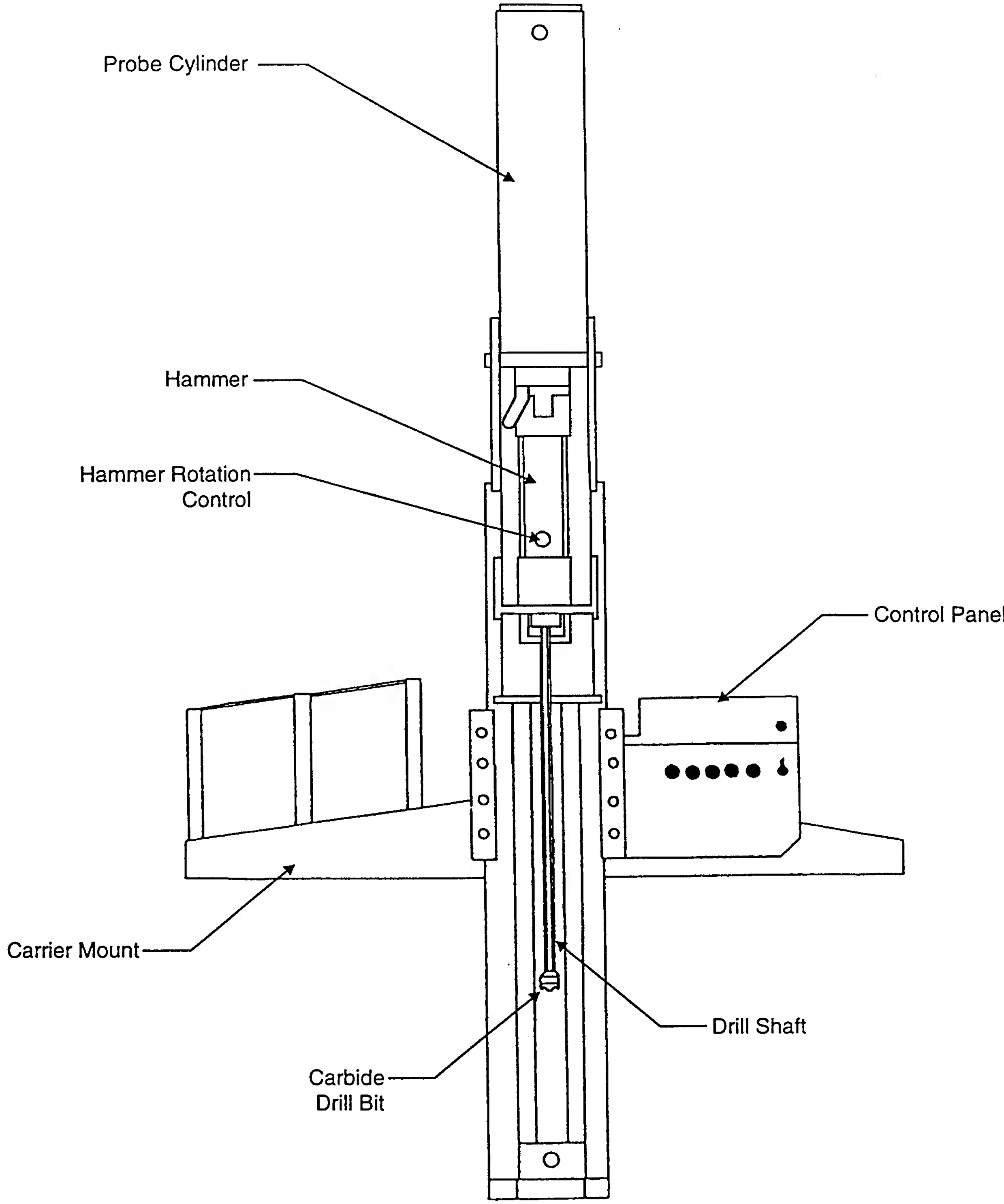

FIGURE 3.2

CROSS SECTION OF GEOPROBE®

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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COREL/DRAW/GEOPROBE.CDR NAP 8/29/95 -TIF

GEOLOGIC BORING LOG

BORING NO.:		CONTRACTOR:		DATE SPUD:	
CLIENT:		RIG TYPE:		DATE CMPL.:	
JOB NO.:		DRLG METHOD:		ELEVATION:	
LOCATION:		BORING DIA.:		TEMP:	
GEOLOGIST:		DRLG FLUID:		WEATHER:	
COMENTS:					

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1											
	5											
	10											
	15											
	20											
	25											
	30											
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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Denver, Colorado

3.1.3 Datum Survey

The horizontal location of all soil sampling locations relative to established Base coordinates will be measured by a surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface also will be measured to the nearest 0.1 foot relative to USGS msl data.

3.1.4 Site Restoration

After sampling is complete, each sampling location that is not converted to use as a groundwater monitoring point will be restored as closely to its original condition as possible. Holes created by the Geoprobe® in sandy soils similar to those found at the Base tend to cave in soon after extraction of the drive sampler. However, any test holes remaining open after extraction of the probe-drive will be sealed with hydrated bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater. Soil sampling using the Geoprobe® creates low volumes of soil waste. Soil not used for sampling will be placed in 55-gallon drums, labeled, and transported to a Base-designated holding location while disposal is being arranged.

3.1.5 Equipment Decontamination Procedures

Prior to arriving at the site, and between each sampling location, probe rods, tips, sleeves, pushrods, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash or Alconox® wash with a potable water rinse. Between each soil sample, the sampling barrel will be disassembled and decontaminated with Alconox® and potable water. The barrel then will be rinsed with deionized water and reassembled with new liners. Between uses, the sampling barrel will be wrapped in clean plastic or foil to prevent contamination. Only potable water will be used for decontamination.

All rinseate will be collected in 55-gallon drums. Filled 55-gallon drums will be labeled and transported to a Base-designated holding location while disposal is being arranged. The Base will be responsible for signing required waste shipping and disposal manifests.

Potable water to be used during equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.2 MONITORING POINT INSTALLATION

To further characterize site hydrogeologic conditions, approximately 16 groundwater monitoring points will be installed at FT-1 to supplement the site monitoring wells. The following sections describe the proposed monitoring point locations and completion intervals, monitoring point installation, monitoring point development, and equipment decontamination procedures.

3.2.1 Monitoring Point Locations and Completion Intervals

The locations of 16 proposed groundwater monitoring points at FT-1 are identified on Figure 3.1. The proposed locations for the new monitoring points were determined from a review of data gathered during previous site activities. Monitoring point locations were selected to provide hydrogeologic data necessary for successful implementation of the Bioplume II model and to monitor potential fuel hydrocarbon migration from the site. Monitoring point locations were selected to define four aspects of the site: 1) the magnitude of the dissolved BTEX concentrations within suspected source areas, 2) the extent of contamination, 3) the horizontal distribution of dissolved BTEX, and 4) the hydrogeology and groundwater flow direction at the site. The proposed locations shown on Figure 3.1 may be modified in the field as a result of encountered field conditions and acquired field data.

Eight monitoring points will be installed within the extent of the gravel pad surrounding the suspected source area. One monitoring point cluster will be installed in the southeastern corner of the burn pit. Another monitoring point cluster will be installed approximately 100 feet downgradient of the burn pit. A third monitoring point cluster will be installed roughly 100 feet upgradient of the burn pit to verify the upgradient limit of contamination. Shallow monitoring points also will be installed approximately 100 feet north and 100 feet south of the burn pit to investigate the lateral extent of contamination to the north and south. The sampling locations are necessary because groundwater in the unconsolidated deposits underlying the gravel pad has not been characterized in previous investigations and is suspected to have elevated concentrations of dissolved BTEX and possibly solvents.

Two deep monitoring points will be installed in the unconsolidated deposits just beyond the downgradient edge of the gravel pad. These deep points will be placed near shallow monitoring wells MW-3 and MW-152 and will aid in determining the vertical extent of contamination in the unconsolidated material immediately downgradient from the suspected source area. Additionally, six shallow monitoring points will be installed downgradient from the gravel pad and at the top of the saturated zone to fully delineate the downgradient extent of contamination and to more accurately characterize the plume downgradient from the gravel pad. Shallow monitoring points will be installed near MW-151, MW-227, MW-226, 150 feet southwest of MW-155, 150 feet north of MW-151, and 250 feet southeast of MW-154. These shallow points will be used to complement existing monitoring well locations for the purpose of full plume delineation. Additional monitoring points and/or the exact placement of monitoring points may be modified by the field scientist as additional site information becomes available.

Each shallow monitoring point will have a screened interval of approximately 3 feet placed near the top of the saturated zone in the unconsolidated deposits. Deep monitoring points will be placed in these deposits immediately above the bedrock basalt. The exact depth and location of monitoring points will be determined by the Parsons ES field scientist on the basis of site conditions. The proposed screened intervals of approximately 3 feet or less will help mitigate the dilution of water samples from potential vertical mixing of contaminated and uncontaminated groundwater in the monitoring point casing. Adjustments of the depth and length of the screened interval

of the monitoring points may be necessary in response to actual aquifer conditions and contaminant distribution identified during Geoprobe® testing.

3.2.2 Monitoring Point Installation Procedures

3.2.2.1 Pre-Placement Activities

All necessary digging, coring, and drilling permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed Geoprobe® locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.1.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2.2.2 Monitoring Point Materials Decontamination

Monitoring point installation and completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, the well points and tubing will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used.

3.2.2.3 Installation and Materials

This section describes the procedures to be used for installation of monitoring points. Monitoring points will be installed using either 0.375-inch Teflon® tubing connected to a 0.5-inch-diameter stainless steel screen or a 0.5-inch inside-diameter (ID)/0.75-inch outside-diameter (OD) polyvinyl chloride (PVC) screen and casing.

If subsurface conditions permit, shallow monitoring points will be constructed of 0.75-inch OD-/0.5-inch-ID PVC casing and well screen to provide additional water level information. Approximately 3 feet of factory-slotted screen will be installed for each shallow monitoring point. Effective installation of the shallow monitoring points requires that the boreholes remain open upon completion of drilling. Shallow 0.5-inch-ID PVC monitoring points will be installed by punching and sampling a borehole with the Geoprobe®. Upon removing the rods, the borehole depth will be measured to determine if the hole remains open. If the borehole remains open, the 0.5-inch-ID PVC casing and screen will be placed at the appropriate depths. The annular space around the screen will be filled with sand filter pack, and the annulus around the casing will be filled with grout or bentonite. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

Monitoring point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 0.5 inch. The screens will be factory slotted with 0.01-inch openings. Shallow monitoring point screens will be placed to sample and provide water level information at or near the water table. Blank monitoring point casing will be

MONITORING POINT INSTALLATION RECORD

JOB NAME ______________________ MONITORING POINT NUMBER ______________

JOB NUMBER ______________ INSTALLATION DATE ______________ LOCATION ______________

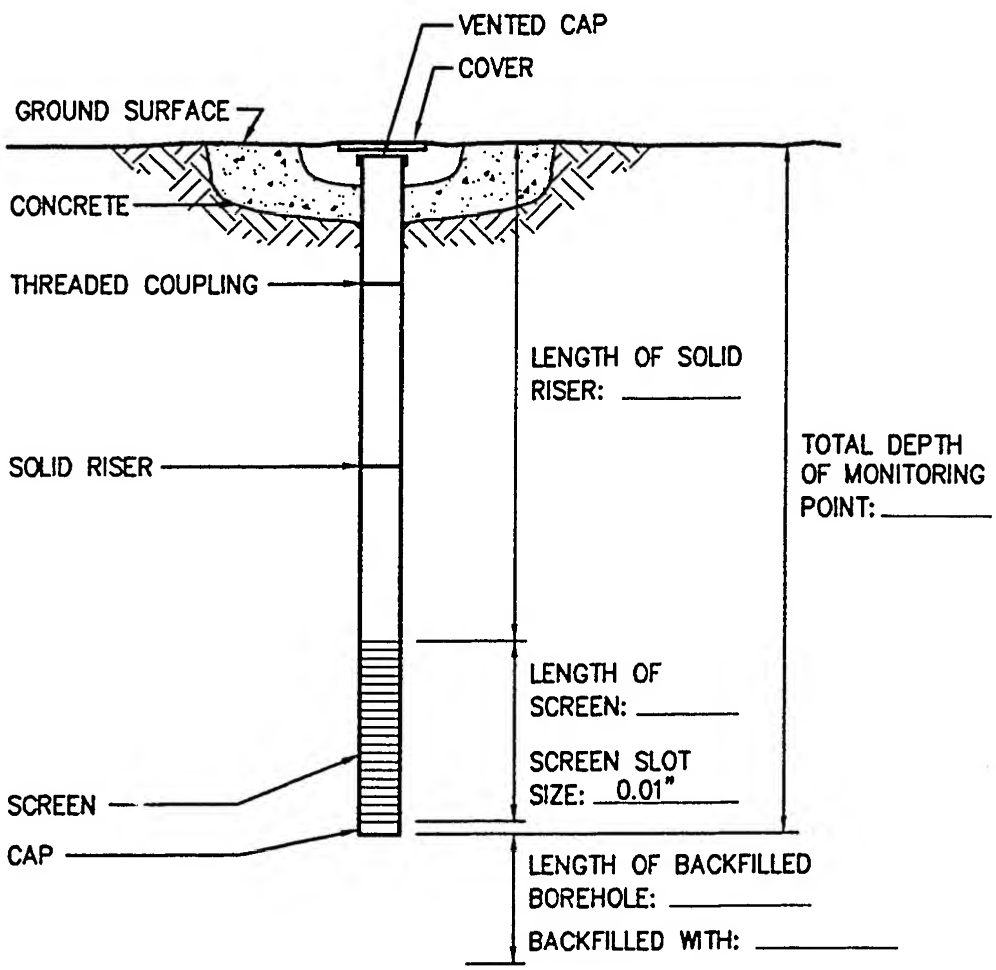
DATUM ELEVATION ______________________ GROUND SURFACE ELEVATION ______________

DATUM FOR WATER LEVEL MEASUREMENT ______________________

SCREEN DIAMETER & MATERIAL ______________________ SLOT SIZE ______________

RISER DIAMETER & MATERIAL ______________________ BOREHOLE DIAMETER ______________

CONE PENETROMETER CONTRACTOR ______________________ ES REPRESENTATIVE ______________



(NOT TO SCALE)

STABILIZED WATER LEVEL ______________ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH ______ FEET BELOW DATUM.

GROUND SURFACE ______________ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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Denver, Colorado

constructed of Schedule 40 PVC with an ID of 0.5 inch. All monitoring point casing sections will be flush-threaded; joints will not be glued. The casing at each monitoring point will be fitted with a bottom cap and a top cap constructed of PVC.

If subsurface conditions do not permit the boreholes to remain open (i.e. the formation collapses in the hole), monitoring points will be constructed of a sacrificial drive point attached to a length of 0.5-inch-diameter stainless steel mesh that functions as the well screen, which in turn is connected to 0.375-inch Teflon® tubing. Holes are less likely to remain open for the installation of the deeper top-of-bedrock wells than the shallower top-of-water-table wells. To install tubing-cased monitoring points, the borehole is punched and sampled to several feet above the target depth for the monitoring point. The probe rods are withdrawn from the borehole, and the soil sampler is replaced with the well point assembly. An appropriate length of Teflon® tubing is threaded through the probe rods and attached to the well point. The assembly is lowered into the borehole and then driven down to the target depth and sampling zone. The probe rods are removed, leaving the sacrificial tip, screen assembly, and tubing behind. The soil is likely to cave in around the screen and tube assembly; where this does not occur, silica sand will be emplaced to create a sand pack around the well point, and the borehole annular space around the tubing above the sand pack will be filled with granular bentonite or grout to seal it. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4).

Should 0.5-inch-ID PVC shallow monitoring points not be installed, the only resulting data gap would be the lack of water level information for that particular location. The decision to install 0.5-inch-ID PVC monitoring points will be made in the field once the open-hole stability of subsurface soils and Geoprobe® equipment can be evaluated.

The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

3.2.2.4 Monitoring Point Completion

Monitoring points will be completed at grade with a protective cover cemented in place. The protective cover will be raised slightly above the ground surface, with a 2-foot-square concrete pad that will slope gently away from the cover to facilitate runoff during precipitation events. After monitoring point completion, each site will be restored as closely as possible to its original condition.

3.2.3 Monitoring Point Development and Records

The new monitoring points will be developed prior to sampling to remove fine sediments from the portion of a formation adjacent to the screen. Development will be accomplished by lowering high-density polyethylene (HDPE) tubing into the well or attaching Teflon® tubing to the pump lines and removing water with a peristaltic pump until pH, temperature, specific conductivity, and water clarity (turbidity) stabilize. At a minimum, 10 casing volumes of water will be developed from each monitoring point. In the event that 10 casing volumes of water cannot be recovered as a result of low water production, the water volume recovered and the deficiency will be noted in the

development records. Monitoring point development will occur a minimum of 24 hours prior to sampling.

A development record will be maintained for each new monitoring point. The development record will be completed in the field by the field scientist. Figure 3.5 is an example of a development record used for similar well installations. Development records will include:

- Monitoring point number;
- Date and time of development;
- Development method;
- Monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and monitoring point depth (0.5-inch ID PVC monitoring points only); and

Field analytical measurements, including pH and specific conductivity.

Development waters will be collected in 55-gallon drums. Filled 55-gallon drums will be labeled and transported to a Base-designated holding location while disposal is being arranged. The Base will be responsible for signing required shipping and disposal manifests.

3.2.4 Monitoring Point Location and Datum Survey

The location and elevation of the monitoring points will be surveyed by a registered surveyor soon after completion. Horizontal coordinates will be measured to the nearest 0.1 foot relative to established Base coordinates. The elevation of the flush-mount casing and measurement datum (top of interior casing) will be measured to the nearest 0.01 foot relative to USGS msl data.

3.2.5 Water Level Measurements

Water levels at all site monitoring points and wells will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe or, if mobile LNAPL is present, an oil-water interface probe.

3.3 GROUNDWATER SAMPLING PROCEDURES

This section describes the scope of work required for collection of groundwater quality samples. Samples will be collected from previously installed monitoring wells and newly installed monitoring points. A peristaltic pump with dedicated HDPE tubing will be used to collect groundwater samples at monitoring points and wells. Samples

MONITORING POINT DEVELOPMENT RECORD

Page__ of__

Job Number: 722450.18
Location: ______________________
Well Number______________________

Job Name: Fairchild AFB, Washington
By____________________ Date________
Measurement Datum____________________

Pre-Development Information

Time (Start):

Water Level:

Total Depth of Well:

Water Characteristics

Color____________________ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material__________________________
pH____________ Temperature(oF oC) ____________
Specific Conductance(µS/cm)______________________

Interim Water Characteristics

Gallons Removed

pH

Temperature (oF oC)

Specific Conductance(µS/cm)

Post-Development Information

Time (Finish):

Water Level:

Total Depth of Well:

Approximate Volume Removed:

Water Characteristics

Color____________________ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material__________________________
pH____________ Temperature(oF oC) ____________
Specific Conductance(µS/cm)______________________

Comments:

FIGURE 3.5

MONITORING POINT DEVELOPMENT RECORD

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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are planned to be collected at monitoring wells MW-1, MW-2, MW-3, MW-4, MW-49, MW-50, MW-52, MW-53, MW-59, MW-61, MW-100, MW-151, MW-152, MW-153, MW-154, MW-155, MW-156, MW-225, MW-226, MW-227, and all 16 new monitoring points (Figures 1.3 and 3.1). In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parson ES and the USEPA NRMRL who are trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference. Groundwater sampling includes the following activities:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity including:
  - Protective cover, cap, and lock,
  - External surface seal and pad,
  - Monitoring well/point stick-up, cap, and datum reference, and
  - Internal surface seal;
- Groundwater sampling, including:
  - Water level and product thickness measurements,
  - Visual inspection of sample water,
  - Monitoring well/point casing evacuation, and
  - Sample collection;
- Sample preservation and shipment, including:
  - Sample preparation,
  - Onsite measurement of physical parameters, and
  - Sample labeling;
- Completion of sampling records; and
- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.3.1 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.1.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the split-spoon soil samplers, sampling pumps, water level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Given the types of sample analyses to be conducted, the following cleaning protocol will be used:

Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);

- Rinse with potable water;
- Rinse with isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling record (Figure 3.6).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the USEPA mobile laboratory's permanent record of the sampling event.

3.3.1.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of dissolved oxygen (DO), pH, electrical conductivity, temperature, reduction/oxidation (redox) potential, sulfate, nitrate, ferrous iron (Fe^{2+}), and other field parameters listed on Table 3.1.

3.3.2 Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The primary ways in which sample contamination can occur is through contact with improperly cleaned sampling equipment. To prevent such contamination, the water level probe and cable used to determine static water levels and total well/point depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.1.1. Dedicated tubing will be used at each well/point developed, purged, and/or sampled with the peristaltic pump. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn each time a different monitoring point or well is sampled. The following paragraphs present the procedures to be followed for groundwater sample collection from groundwater monitoring points and wells. These activities will be performed in the order presented

GROUNDWATER SAMPLING RECORD

SAMPLING LOCATION ____________________
SAMPLING DATE(S) ____________________
MONITORING WELL ____________________
(number)

REASON FOR SAMPLING: [ ] Regular Sampling; [ ] Special Sampling;
DATE AND TIME OF SAMPLING: ______________, 19___ __________ a.m./p.m.
SAMPLE COLLECTED BY: ____________________ of ____________________
WEATHER: ____________________
DATUM FOR WATER DEPTH MEASUREMENT (Describe): ____________________

MONITORING WELL CONDITION:
[ ] LOCKED: [ ] UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: ____________________
INNER PVC CASING CONDITION IS: ____________________
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
[ ] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
[ ] MONITORING WELL REQUIRED REPAIR (describe): ____________________

Check-off
1 [ ] EQUIPMENT CLEANED BEFORE USE WITH ____________________
Items Cleaned (List): ____________________

2 [ ] PRODUCT DEPTH ____________________ FT. BELOW DATUM
Measured with: ____________________

WATER DEPTH ____________________ FT. BELOW DATUM
Measured with: ____________________

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: ____________________
Odor: ____________________
Other Comments: ____________________

4 [ ] WELL EVACUATION:
Method: ____________________
Volume Removed: ____________________
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: ____________________
Other comments: ____________________

FIGURE 3.6

GROUNDWATER SAMPLING RECORD

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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Denver, Colorado

GROUND WATER SAMPLING RECORD (Continued)

MONITORING WELL ______________

5 [ ] SAMPLE EXTRACTION METHOD:

[ ] Bailer made of: ______________
[ ] Pump, type: _
[ ] Other, describe: ______________

Sample obtained is [ ] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Temp: ________ ° ______	Measured with: ______________
pH: ______________	Measured with: ______________
Conductivity: __________	Measured with: ______________
Dissolved Oxygen: __________	Measured with: ______________
Redox Potential: __________	Measured with: ______________
Salinity: __________	Measured with: ______________
Nitrate: __________	Measured with: ______________
Sulfate: __________	Measured with: ______________
Ferrous Iron: __________	Measured with: ______________

Other: ______________

7 [ ] SAMPLE CONTAINERS (material, number, size): ______________

8 [ ] ON-SITE SAMPLE TREATMENT:

[ ] Filtration:

Method ______________	Containers: ______________
Method ______________	Containers: ______________
Method ______________	Containers: ______________

[ ] Preservatives added:

Method ______________	Containers: ______________
Method ______________	Containers: ______________
Method ______________	Containers: ______________
Method ______________	Containers: ______________

9 [ ] CONTAINER HANDLING:

[ ] Container Sides Labeled
[ ] Container Lids Taped
[ ] Containers Placed in Ice Chest

10 [ ] OTHER COMMENTS: ______________

FIGURE 3.6 (Continued)

GROUNDWATER SAMPLING RECORD

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

below. Exceptions to this procedure will be noted in the field scientist's field notebook or on the groundwater sampling record.

3.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the monitoring points/wells will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring point/well.

3.3.2.2 Water Level and Total Depth Measurements

Prior to removing water from the monitoring point/well, the static water level will be measured. An electric water level probe or oil/water interface probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring point/well and the depth will be measured to the nearest 0.01 foot. If free-phase product (mobile LNAPL) is present, the total depth of the well from installation records will be used to avoid excessive contamination of the water level probe and cord. Based on these measurements, the volume of water to be purged from the monitoring point/well will be calculated. If mobile LNAPL is encountered, the thickness of the product will be measured with an oil/water interface probe.

3.3.2.3 Monitoring Point/Well Purging

The volume of water contained within the monitoring point/well casing at the time of sampling will be calculated, and at least three times the calculated volume will be removed from the well. A peristaltic pump will be used for monitoring point/well purging. All purge waters will be collected in 55-gallon drums. Filled 55-gallon drums will be labeled and transported to a Base-designated holding location while disposal is being arranged. The Base will be responsible for signing required shipping and disposal manifests.

If a monitoring point or well is evacuated to a dry state during purging, the point/well will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring point/well to obtain the necessary sample quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

3.3.2.4 Sample Extraction

Dedicated HDPE tubing and a peristaltic pump will be used to extract groundwater samples from monitoring points and wells. The tubing will be lowered through the casing into the water gently to prevent splashing. This step is omitted if the monitoring point is constructed of Teflon® tubing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the USEPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be disposed of in the same manner as purge water.

3.3.3 Onsite Groundwater Parameter Measurement

As indicated on Table 3.1, many of the groundwater chemical parameters will be measured onsite by USEPA staff. Some of the measurements will be made with direct-reading meters, while others will be made using a HACH® portable colorimeter in accordance with specific HACH® analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of laboratory-grade, phosphate-free detergent (e.g., Alconox®) and water, and rinsing with isopropyl alcohol and deionized water to prevent interference or cross-contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric or colorimetric methods, the analysis will be repeated by diluting the groundwater sample with distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps and properly disposed.

3.3.3.1 Dissolved Oxygen Measurements

DO measurements will be made using a meter with a downhole oxygen sensor or a sensor in a flow-through cell before and immediately following groundwater sample acquisition. When DO measurements are taken in monitoring points/wells that have not yet been sampled, the monitoring points/wells will be purged until DO levels stabilize.

3.3.3.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a flow-through cell or a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded in the groundwater sampling record (Figure 3.6).

3.3.3.3 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced USEPA NRMRL scientists via titrimetric analysis using USEPA-approved HACH® Method 8221 (0 to 5,000 mg/L as calcium carbonate) or a similar method. Alkalinity of the groundwater

sample also will be measured at the fixed-based laboratory using USEPA method 310.1.

3.3.3.4 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced USEPA NRMRL scientists via colorimetric analysis using a HACH® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with HACH® Method 8039 (0 to 30.0 mg/L NO_3). Nitrite concentrations in groundwater samples will be analyzed after preparation with EPA-approved HACH® Method 8507 (0 to 0.35 mg/L NO_2) or a similar method.

3.3.3.5 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by USEPA NRMRL scientists via titrimetric analysis using HACH® Method 1436-01 (0 to 250 mg/L as CO_2). Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.3.

3.3.3.6 Sulfate Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments. A USEPA NRMRL scientist will measure sulfate concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter. After appropriate sample preparation. EPA-approved HACH® Method 8051 (0 to 70.0 mg/L SO_4) or similar will be used to prepare samples and analyze sulfate concentrations.

3.3.3.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the redox potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® Method 8008 (or similar) for total soluble iron (0 to 3.0 mg/L Fe^{3+} + Fe^{2+}) and HACH® Method 8146 (or similar) for ferrous iron (0 to 3.0 mg/L Fe^{2+}) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.3.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis

with a HACH® DR/700 Portable Colorimeter. USEPA-approved HACH® Method 8034 (0 to 20.0 mg/L) or similar will be used for quantitation of manganese concentrations. Sample preparation and disposal procedures are outlined earlier in Section 3.3.3.

3.3.3.9 Reduction/Oxidation Potential

The redox potential of groundwater is an indication of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potential can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a groundwater sample taken inside the contaminant plume should be somewhat less than that taken in an upgradient location.

The redox potential of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis or in a flow through cell.

3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to USEPA field laboratory.

3.4.1 Sample Preservation

The USEPA mobile laboratory support personnel will add any necessary chemical preservatives prior to filling the sample containers. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of as close to 4 degrees centigrade (°C) as possible. Samples will be delivered promptly to USEPA field laboratory personnel, who will be responsible for shipment of appropriate samples to the NRMRL in Ada, Oklahoma for analysis.

3.4.2 Sample Containers and Labels

Sample containers and appropriate container lids will be provided by the USEPA field laboratory (see Appendix A). The sample containers will be filled as described in Section 3.3.2.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., groundwater, soil);

- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the onsite USEPA field laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the USEPA field laboratory. Delivery will occur as soon as possible after sample acquisition.

3.4.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the USEPA field laboratory to the NRMRL analytical laboratory in Ada, Oklahoma, will be the responsibility of the USEPA field personnel.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance, and

- Sample odor;

- Weather conditions;
- Water level prior to purging (groundwater samples only);
- Total monitoring well/point depth (groundwater samples only);
- Sample depth (soil samples only);
- Purge volume (groundwater samples only);
- Water level after purging (groundwater samples only);
- Monitoring well/point condition (groundwater samples only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (groundwater samples only); and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.6 shows an example of the groundwater sampling record. Soil sampling information will be recorded in the field log book.

3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater and soil samples as well as the QA/QC samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, USEPA NRMRL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with USEPA protocol or those reported in Appendix A of this plan.

USEPA laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory. Containers, ice chests with adequate padding, and cooling media will be provided by USEPA NRMRL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the field laboratory.

3.5 AQUIFER TESTING

Slug tests will be conducted in selected monitoring wells to estimate the hydraulic conductivity of unconsolidated deposits at the site. This information is required to accurately estimate the velocity of groundwater and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity

of less than 7,000 ft^2/day. Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

3.5.1 Definitions

- **Hydraulic Conductivity (K)**. A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.

- **Transmissivity (T)**. A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.

- **Slug Test**. Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.

- **Rising Head Test**. A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.

- **Falling Head Test**. A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.5.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon®, PVC, or metal slugs;

- Nylon or polypropylene rope;

- Electric water level indicator;

- Pressure transducer/sensor;

- Field logbook/forms; and

- Automatic data recording instrument (such as the Hermit Environmental DataLogger®, In-Situ, Inc. Model SE1000B, or equivalent).

3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and

then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Slug testing will proceed only after multiple water level measurements over time show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; in addition, slug tests will not be performed on wells with free product. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.3.1.1.

3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.

2. Open the well. Where wells are equipped with watertight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing should remain locked during this time to prevent vandalism.

3. Prepare the aquifer slug test data form (Figure 3.7) with entries for:

- Borehole/well number,
- Project number,
- Project name,
- Aquifer testing team,
- Climatic data,
- Ground surface elevation,
- Top of well casing elevation,
- Identification of measuring equipment being used,
- Page number,
- Static water level, and
- Date.

4. Measure the static water level in the well to the nearest 0.01 foot.

AQUIFER SLUG TEST DATA SHEET

Location: ______________________ Client: AFCEE Well No. ____________

Job No.: 722450.18 Field Scientist ____________ Date ____________

Water Level ______________________ Total Well Depth ______________________

Measuring Datum ______________________ Elevation of Datum ______________________

Weather ______________________ Temp ______________________

Comments ____

____

Beginning Time	Ending Time	Initial Head Reading	Ending Head Reading	Test Type (Rise/Fall)	File Name	Comments

FIGURE 3.7

AQUIFER TEST DATA FORM

Site FT-1
Intrinsic Remediation TS
Fairchild AFB, Washington

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5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.

6. Lower the decontaminated slug into the well to just above the water level in the well.

7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.

8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.

2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.

3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV™ and the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined aquifer conditions.

SECTION 4

TS REPORT

Upon completion of field work and modeling, a TS report detailing the results of the investigation and subsequent modeling will be prepared. This report will follow the outline presented in Table 4.1. It will contain an introduction, a summary of physical characteristics, a discussion of the nature and extent of contamination (including geochemistry), a description of selected remedial alternatives, a groundwater model, and a proposed long-term monitoring plan.

TABLE 4.1
EXAMPLE TS REPORT OUTLINE
FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

INTRODUCTION
- Scope and Objectives
- Site Background

SITE CHARACTERIZATION ACTIVITIES
- Sampling and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA
- Surface Features
- Regional Geology and Hydrogeology
- Site Geology and Hydrogeology
- Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION
- Source Characterization
- Soil Chemistry
  - Residual Contamination
  - Total Organic Carbon
- Groundwater Chemistry
  - LNAPL Contamination
  - Dissolved Contamination
  - Groundwater Geochemistry
  - Expressed Assimilative Capacity

DESCRIPTION OF SELECTED REMEDIAL ALTERNATIVES
- Bioventing
- Air Sparging

GROUNDWATER MODEL
- Model Description
- Conceptual Model Design and Assumptions
- Initial Model Setup
- Model Calibration
- Sensitivity Analysis
- Model Results
- Conclusions

LONG-TERM MONITORING PLAN
- Overview
- Monitoring Networks
- Groundwater Sampling

CONCLUSIONS AND RECOMMENDATIONS

APPENDICES: Supporting Data and Documentation
Site-Specific Bioplume II Model Input and Results

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field replicates/duplicates and rinseate, field and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of as close to 4°C as possible.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate groundwater and soil samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Soil and groundwater samples collected with the Geoprobe® sampler should provide sufficient volume for some replicate and duplicate analyses. Refer to Table 3.1 and Appendix A for further details on sample volume requirements.

One rinseate sample will be collected for every 10 or fewer groundwater samples collected from existing wells. Rinseate samples will consist of a sample of distilled water poured into or pulled through decontaminated or new sampling equipment and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

A field blank will be collected for every 20 or fewer groundwater samples (both from groundwater monitoring point and groundwater monitoring well sampling events) to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

TABLE 5.1
QA/QC SAMPLING PROGRAM
FT-1 INTRINSIC REMEDIATION TS
FAIRCHILD AFB, WASHINGTON

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	4 Groundwater and 2 Soil Samples (10%)	VOCs, TPH
Rinseate Blanks	2 Samples (5% of Groundwater Samples)	VOCs
Field Blanks	2 Samples (5% of Groundwater Samples)	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory. A trip blank will be transported inside each cooler which contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

SECTION 6

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APPENDIX A

CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING REQUIREMENTS FOR GROUNDWATER SAMPLES

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Volatile organics	Gas chromatography/ mass spectrometry method SW8240.	Handbook method	Data is used to determine the extent of chlorinated solvent and aromatic hydrocarbon contamination, contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon®-lined cap; cool to 4°C	Fixed-base
Soil	Dehydrogenase enzyme activity (optional)	Colorimetric RSKSOP-100	Reduction of added triphenyltetrazolium chloride by soil microbes is measured colorimetrically; analyze immediately	An indicator of the presence of soil microbes, which are necessary for bioremediation to occur	At the beginning of the project	Collect 100 g of soil in a glass container	Field
Soil	Aromatic hydrocarbons (benzene, toluene, ethyl-benzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base
Soil gas	Carbon dioxide content of soil gas	Nondispersive infrared instrument operating over the range of approximately 0.1–15 percent	Soil gas carbon dioxide may be produced by the degradation of petroleum hydrocarbons	Data used to understand the carbon dioxide concentration gradient with depth and to infer the biological degradation of petroleum contaminants	Each sampling round	N/A	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil gas	Oxygen content of soil gas	Electrochemical oxygen meter operating over the range of 0–25 percent of oxygen in the soil gas sample	The concentration of soil gas oxygen is often related to the amount of biological activity, such as the degradation of petroleum hydrocarbons; soil gas oxygen concentrations may decrease to the point where anaerobic pathways dominate	Data are used to understand the oxygen concentration gradient with depth and to determine the presence or absence of aerobic degradation processes	Each sampling round	N/A	Field
Soil gas	Methane content of soil gas	Total combustible hydrocarbon meter using a platinum catalyst with a carbon trap, and operating in the low parts per million volume (ppmv) range	Methane is a product of the anaerobic degradation of petroleum hydrocarbons	Soil gas methane can be used to locate contaminated soil and to determine the presence of anaerobic processes; see discussion of data use for methane in water	Each sampling round	N/A	Field
Soil gas	Fuel hydrocarbon vapor content of soil gas	Total combustible hydrocarbon meter operating over a wide ppmv range	Soil gas hydrocarbons indicate the presence of these contaminants in the soil column	Data used to understand the petroleum hydrocarbon concentration gradient with depth and to locate the most heavily contaminated soils	Each sampling round	N/A	Field
Water	Ferrous (Fe^{+2})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 ml of water in a glass container; acidify with hydrochloric acid per method	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ferrous (Fe^{+2})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above	Each sampling round	Collect 100 ml of water in a glass container	Field
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl^- C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen *in situ*	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100–250 mL of water in a glass or plastic container	Field
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 100mL of water in glass container	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	Same as above	Each sampling round	Collect 250 mL of water in a glass or plastic container; analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base
Water	Nitrate (NO_3^{-1})	HACH method # 8039 for high range method # 8192 for low range	Colorimetric	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH method # 8051	Colorimetric	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Field
Water	Dissolved sulfide (S^{-2})	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 100 mL of water in a glass container; analyze immediately	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Methane; carbon dioxide	RSKSOP-114 modified to analyze water samples for methane and carbon dioxide by headspace sampling with dual thermal conductivity and flame ionization detection (also, see reference in note 10)	Method published and used by the U.S. Environmental Protection Agency (EPA) Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis); a redox potential measurement of less than -200 mV could be indicative of methanogenesis and should be followed by the analysis referenced here; the presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ethane, ethene	RSKSOP-114 (cont'd)	Ethane and ethene are analyzed in addition to the other analytes only if chlorinated hydrocarbons are contaminants suspected of undergoing biological transformation	Ethane and ethene are products of the bio-transformation of chlorinated hydrocarbons under anaerobic conditions. The presence of these chemicals may indicate that anaerobic degradation is occurring			
Water	Carbon dioxide	HACH test kit model CA-23 or CHEMetrics Method 4500	Titrimetric; alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect 100 mL of water in a glass container	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling	One time per year or as required by regulations	Volatile hydrocarbons–collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons–collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base
Water	Volatile Organics	GS/MS method SW8240	Handbook method	Method of analysis for chlorinated solvents and aromatic hydrocarbons for evaluation of cometabolic degradation; measured for regulatory compliance when chlorinated solvents are known site contaminants	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; it may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100–250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to *Robert S. Kerr (Environmental Protection Agency Laboratory) Standard Operating Procedure*.
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.

Log of Borehole

Borehole MW-149

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Project Fairchild AFB (TVA)
Location FT1-LOC14-MW-149
Geologic Log by Catherine Olsen
Driller Dan /Env. West
Geophysics by NA
Weather 40°F, prt cldy

Total Depth 14.0 ft
Borehole Dia 6-inch
Depth to Fluid —
Rig Mobile Drill B-61
Bit(s) Hollow-stem auger
Fluid None

	START	FINISH
Date	11-11-91	11-11-91
Time		

How Left Protective steel csg w/brass survey markers.

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0							0-2.0 ft: Silty snds, v. fine to med grn snds, occas. 8-10 mm bslt clsts, organic soils to 0.6', dry, loose, 10YR 6/3	
2							2.0-4.0 ft: silty snds, v. fine to med. snds, bslt pebbles 4-50 mm, subang to subrnd, loose, dry, 10YR 5/3	
4							4.0-6.0 ft: Silty snds w/trace clay; fine to med snds (micaceous), occ. 20-30 mm bslt pble, 10YR 3/2, sl. moist mottled 10YR 5/6.	
6							6.0-8.0 ft: Clayey silts w/minor snds, sl. moist, 7.0-7.25' v. crs grn sand lens, clay @ 7.25-8.0', plstc, sl. moist	
8							8.0-10.0 ft: Silty sands, v. wet fine to med snds, 10YR 3/1, roots observed, 9.5-10.0' fine to med snds to silty snd 5Y 4/1	
10							10.0-12.0 ft: Clayey silt (10-10.5') moist, 10YR 3/2, 10.5-12.0' silty snds, med to v. crs snds, wet, 10YR 5/3	
12							12.0-14.0 ft: Silty sands to 14.0 ft, Clay @ 14.0 ft.	
Total Depth @ 14.0'							Total Depth @ 14.0 ft.	

MW-150

Borehole FT- LOC 12

page 1 of 2

Log of Borehole

Project FAIRCHILD AFB	Total Depth 43'	START FINISH
Location FIRE TRAINING MW150	Borehole Dia ~~10"~~ 8"	Date 9/18/91 9/20/91
Geologic Log by CHUCK HOUCK SAIC	Depth to Fluid 15' 1st encountered	Time 1350 1600
Driller LOUIE - PONDEROSA	Rig CP - ~~780~~	How Left 2.5' AGS
Geophysics by	Bit(s) Tri cone - Rock Hammer	w/steel security
Weather sunny warm, sl breeze	Fluid Air/H_2O	box in place

Time	Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
	0								
	5								
	10							No Collection to 14' bgs - ream pilot hole	
1415	15	NA	2 gpm	Ø	1	15	CL	Clay, with f-m sand, dk yellowish brown 3/1 10YR, soft	
1425	20	0.5	2 gpm	Ø	2	20	SW	Granular Sand, v-coarse, ~~pebbles~~ sand < 15mm tr clay frag, black, angular to subrounded >90% basalt, tr feld + quartz	
1520	25		2 gpm	Ø	3	25	SP/SW	Sand, f- v coarse, ~~some~~ granules, trace pebbles < 8 mm, ~~dk~~ ~~grayish~~ brown black 2.5/0 2.5 yr poorly sorted, angular to subrounded, >90% basalt - *Hard rock @ 28'+ loss of air press	
1618	30		2	Ø	4	30.5	BR	Basalt - fractured - v dark gray 3/0 2.5 Y	
							ML	*soft spot sandy silt ~ 2' thick	

* driller comments

Borehole FT-1 Loc 12

Log of Borehole

Project FAIRCHILD AFB	Total Depth 43'	START / FINISH
Location FT-1 Loc 12	Borehole Dia 8"	Date 9/18/91 9/20/91
Geologic Log by C. Houck - SAIC	Depth to Fluid ~15 first encountered	Time 1350 1400
Driller Louie - PONDEROSA	Rig CP 708	How Left 2.5 ABS
Geophysics by	Bit(s) TRICONE - Rock HAMMER	w/steel security box
Weather sunny warm	Fluid H_2O/AIR	in place

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
1422 36	1.2	2	0	5	36	BR	Hard again @ 36- Fractured Basalt dk gray, some felsic sand, angular, rd/brown	
1427 40	1.0	2	0	6	40		Basalt - ~~...~~ black 2.5Y - fractured	
1632	0.6	2	0	7	43	BR	Basalt - some fine sand, black 2.5Y less fractured - Harder drilling*	
45							TD - 43'	

* drillers comments

MW151

Borehole FT-1 Loc 2

Log of Borehole

page 1 of 1

Project FAIRCHILD AFB	Total Depth 31.5'	START / FINISH
Location FT-1 Loc 2 MW151	Borehole Dia 8"	Date 9/21/91 9/21/91
Geologic Log by CHUCK Houck SAIC	Depth to Fluid	Time 0800 1400
Driller PONDEROSA - Louie	Rig CP 780	How Left pvc casing
Geophysics by	Bit(s) 8" tricone	no security box as of
Weather	Fluid Air/water	9/21/91

Time	Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
	0								
0830	10		2	3.0	1	10		Sandy gravel with pebbles <15mm poorly sorted - subangular to subrounded, vesicular + fractured basalt some feld & quartz	
0843	15		2	3.5	2	15		sandy gravel, some silt pebbles <10mm brown silt, ~~sub~~ angular to subrounded >90% basalt - bedrock 15.5' ~~feet~~	
0855	20		2	13	3	20		Fractured basalt, black 2/0 2.5y some fine sands, to silt - easy drilling ~~[illegible]~~ ~23' ~~[illegible]~~ * ck driller said the drilling firmed up ~19' - soft ~24'	
0930	25		2	2.5	4	25		massive basalt black 2/1 10YR - hard	
1016	30		2	11	5	30		basalt as above	
			2	1.0	6	31.5		basalt as above TD 31.5 (1022h)	

* missed depth - disregard

Borehole Loc #13

Log of Borehole

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Project FAFB	Total Depth 12'	START / FINISH
Location FT-1 / MW-152	Borehole Dia ~~8~~ 8"	Date 11-12-91 / 11-12-91
Geologic Log by G. DiGregorio	Depth to Fluid 4.8'	Time 1145 ~~1220~~ / 1220
Driller Dan Claassen/Environ West	Rig Mobile Drill B61	How Left
Geophysics by NA	Bit(s) 8" Augers	w/ locking well
Weather overcast 40°F breezy	Fluid NA	monument

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	~~OVA~~ HNU ~~sample~~ hole/ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0							silty clay dry non-plastic w/ organics dark brown	
2			1 / .2		0-2			75%
							silty sandy clay ~~w/~~ dark brown moist easy drilling ~~wet at 3'~~ 40	
4			5 / 10		2-4			50%
						∇	silty sandy clay dark brown change to coarse sand, well sorted, angular w/ greenish gray clay @ 4.8' basalt, qtz & felds	
6			5 / 12		4-6			75%
							Sand coarse grain well sorted angular, minor gravel ≤ 30 mm basalt, qtz and felds.	
8			8 / 8.6		6-8			80%
							Sand coarse grain well sorted ~~to~~ angular w/ minor gravel ≤ 30 mm.	
10			8 / 8		8-10			50%
							Drilled to 12' spoon refusal at 11'. Coarse sand w/ weathered basalt gravel ≤ 40 mm Auger refusal @ 12' TD	
12			0		—			~~85%~~ 60

HNu Background 0.0 ppm

MW-153

Borehole Loc #17

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Log of Borehole ...

Project FAFB	Total Depth 9½'	START FIN
Location FT-1 / MW-153	Borehole Dia 8"	Date 11-13-91 11-13-91
Geologic Log by G. DiGregorio	Depth to Fluid 4.8' BGS	Time 0726 0800
Driller Dan Claassen/Envicon. West	Rig Mobile Drill 361	How Left w/ locking well vault in place
Geophysics by NA	Bit(s) 8" Auger	
Weather Clear Cold 32°F	Fluid NA	

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	~~OVA/~~ HNU sample/ hole ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0							silty clay w/ organics dark brown grading to very silty clay yellowish brown at 1.4' dry non-plastic w/ coarse sand.	
2			0/0		0-2			75%
							silty clay w/ sand dry non plastic grading to coarse sand w/ basalt gravel ≤ 20 mm @ 3.01' BGS Refusal (spoon) at 2.5'	
4			0/0		2-4			10% 25%
							Coarse sand w/ minor gravel ≤ 6 mm ang, wellsorted Wet @ 4.8' Basalt, qtz and felds, minor FeOx staining	
6			0/0		4-6			60%
							Sand coarse well sorted w/ basalt gravel spoon refusal @ 6.5' BGS	
8			0/0		6-6.5			100%
							Sand, coarse, well sorted angular w/ basalt gravels	
							TD @ 9' BGS	

HNu Background 0.0 ppm

MW154

Log of Borehole

Borehole FT-1 Loc 11

page 1 of 1

Project Fairchild AFB	Total Depth 31'	START / FINISH
Location FT-1 Loc 11 MW154	Borehole Dia 8"	Date 9/21/91 9/22/91
Geologic Log by Chuck Howk (SAIC)	Depth to Fluid	Time 1600 0845
Driller Lowe Hanson Bonanza	Rig CP 780	How Left grout ~ 2' bgs
Geophysics by	Bit(s) 8" Tricone	and pvc 2.5 AGS w/
Weather Warm windy	Fluid AIR/WATER	dry cap - no security

Time	Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
	0								
1600	5		0	8	1	5		f-vcoarse sand, some granules and pebbles <10mm, dry, poorly sorted basalt, feldspar, quartz ~~mottling~~	
1624	10		2	16.2	2	10		med-coarse sand, tr vcoarse, mod well sorted, quartz, basalt, feldspar subangular to subrounded	
1627	15		2	18.8	3	15		f-coarse, tr gravel/pebbles <10mm silty sand, lt yellowish brown, 3/4 10YR poorly sorted v wet basalt-lastined/weathered @15.5 - hardened up ~ 19' on drill	
0911	20		~~222~~	7.2	4	20		basalt - massive - black 2.5Y/ 5Y tr yellow gray silt and feldspar fine sand	9/22/91
0919	25		2	19.8	5	25		basalt - hard black 2.5/ 5Y tr weathered/fract basalt fragments	
0926	30		2	3.8	6	30			
0928	31							basalt - hard - black 2.5/ 5Y TD 31' bgs	

MWIS5

Borehole Loc #16

page 1 of 1

Log of Borehole

Project FAFB	Total Depth 9'		START	FIN
Location FT-1 / MW-155	Borehole Dia 8"	Date	11-12-9[illegible]	11-12-9[illegible]
Geologic Log by G. DiGregorio	Depth to Fluid 5'	Time	1336	1407
Driller Dan Claassen/Envirom West	Rig Mobile Drill B61	How Left	w/ locking well vault in place	
Geophysics by NA	Bit(s) 8" Auger			
Weather overcast 40°F	Fluid NA			

Depth	Pene. Rate/ Blow Cts	Circu- lation Q (gpm)	~~OVA~~ HNU sample/bg ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0							silty clay dry non-plastic organics w/ minor sand dark brown	
2			4/10		0-2			90%
							sandy clay grading to coarse sand @ 3'. Basalt qtz & felds w/ FeOx staining grading to weathered vesicular basalt gravel is sub ≤ 30 mm	
4			2/2		2-4			75%
							sand w/ minor clay to 5' grading to coarse sands angular well sorted. Water @ 5'	
						∇		
6			6/8		4-6			75%
							sand, coarse grain well sorted angular, basalt qtz & felds basalt gravel w/ FeOx ~~staining~~ staining @ 8' angular ≤ 15 mm	
8			5/1		6-8			75%
							coarse sand well sorted angular w/ basalt gravel ≤ 30 mm angular FeOx staining, [illegible] refusal @ 8.6	
10			0/0		8-10			25%
							Drilled to ~~10.5~~ 9.00 Auger refusal @ ~~10.5~~ 9' TD well	

MWI5C

Borehole FT-1 loc 1

Log of Borehole

page 1 of 2

Project FAIRCHILD AFB	Total Depth 43.5	START / FINISH
Location FT-1 loc 1 MWI5C	Borehole Dia 8"	Date 9/22/91 9/23/91
Geologic Log by C. Honck SAIC	Depth to Fluid	Time 1415 1030
Driller PONDEROSA - Louie HANNER	Rig CP 780	How Left grout to
Geophysics by	Bit(s) 8" Tricone / hammer	surface - pvc 2.5 AGS
Weather	Fluid AIR / WATER	no security box

Time	Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
	0								
1450	5		0	0	1	5		Clayey sand, f-m, dk red brown 3/1 5YR Sandy clay, soft	
1453	10		0	0	2	10		f-m sand, tr silt, black 2.5/1 5YR mod sorted, basalt, quartz, feldspar subangular-rounded	
1459	15		0	0	3	15		f-coarse sand, ~~tr pebble~~ coal granule and tr small bits of clay dk brown, ~~poorly~~ mod sorted, subangular to subrounded basalt, quartz 3/2 7.5YR Thinly bedded clay lense - w/in fine sand and silt dk brn 4/4	
1612	20		2		4	20		gravelly sand, f-coarse, some pebbles, poorly sorted, angular to subrounded, basalt, quartz, feld, plag Bed rock @ 23.5' per driller	
1649	25		2	3.5	5	25		Sand - fine-med, well sorted subang - sub-round and Fractured basalt - black	
1719	30		2	5	6	30		basalt - massive hard - black 2/0 2.5Y	

MW 156

Borehole FT-1 Loc 1

Log of Borehole

page 2 of 2

Project FAIRCHILD AFB	Total Depth 8 43.5	START FINISH
Location FT-1 Loc 1 MW156	Borehole Dia 8"	Date 9/22/91 9/23/91
Geologic Log by C Houck SAIC	Depth to Fluid	Time 1415 1030
Driller Louie Hanner - Ponderosa	Rig CP 780	How Left grout to surface
Geophysics by	Bit(s) 8" Tricone/hammer	w/PVC 2.5 AGS - no
Weather	Fluid Air/Water	security box

	Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
1712	35		2	0	87	35		Basalt as above	
1722	40		2	0	8	40		Basalt as above	
								TD 43.5 - Basalt - no change	
1728									

MW-157

Borehole FT-1 Sand ...

Log of Borehole

page 1 of 2

Project FAIRCHILD AFB	Total Depth 39.5'	START / FINIS
Location FT-1 Shal Pump #2 Loc. 5 MW-157	Borehole Dia 8"	Date 10/7/91
Geologic Log by A. Civazos, SAIC / Chuckchance, SAIC	Depth to Fluid	Time 0815
Driller Louie Henner, Ponderosa	Rig CP 7000	How Left
Geophysics by NA	Bit(s) 8' tricone roller, 8" hammer bit	well vault in place
Weather 50° partly sunny	Fluid air, water	and grouted

Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description
0							
0830 — 5			1.0	1	5		Sandy Gravel; very coarse sand and granules and pebbles (<25mm); moderately sorted; dk grysh brn to yelsh brn; subrnd to ~~sub~~ ang; trace quartz
0848 — 10			0.2	2	10		Sandy Gravel; very coarse sand, granules and pebbles (<30mm); dk grysh brn to yelsh brn; mod sorted; subrnd to ang
0852 — 15			0.4	3	15		Sandy Gravel; fine to coarse sand, granules and pebbles (<30mm); dk grysh brn to yelsh brn; mod sorted; subrnd to subang
0900 — 20			0.2	4	20		Basalt; massive; black; some coarse sand granules + pebbles (<10mm) in sample ~~...~~ translucent white coating on surface of some basalt frags
25			0.0	5	25		Basalt, coarse grained w/ minor discoloration light gray — 10/8/91
30			0.0	6	30		Basalt, coarse grained, fractures at ~32' - 35', yellowish coating

MW-157

Borehole FT-1 shallow p.

page 2 of 2

Log of Borehole

Project Fairchild AFB	Total Depth 39.5'		START / FIN
Location FT-1 Shallow pump #2 MW-157	Borehole Dia 8"	Date	10/7/91 / 10/14/91
Geologic Log by DiGregorio	Depth to Fluid	Time	0815 / 1005
Driller Louie Hemmel / Ponderosa	Rig CP 7000	How Left	Locking well vault in place and grouted
Geophysics by NA	Bit(s) 8" tricone roller, 8' hammer bit		
Weather partly cloudy 45°F	Fluid water		

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
35					35'	^ ^ ^	Basalt, coarse grained, fractures with yellowish-green coating, glassy; dark gray	
							TD ≈ 38'	

MW-158

Borehole FT-1 [illegible]

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Log of Borehole

MW158

Project FAIRCHILD AFB	Total Depth 91'	START FIN
Location FT-1 ~~[illegible]~~ mud pump LOC #3	Borehole Dia 5"	Date 10/3/91 10/
Geologic Log by A. Cruz SAIC	Depth to Fluid 5'	Time 0740 15
Driller / Heimer, Anderson	Rig CP 7000	How Left Mounted
Geophysics by	Bit(s) 5" air rotary 5" [illegible] bit	security box, no L
Weather 70° Sunny	Fluid air, water	

Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description
0							
5			9.0	1	5		Sand, gravel; pebbles (<30mm); some granules and coarse sand; v[illegible] gray lt yel-brn; mod sorted; rounded to subang; granules; subang to ang pebbles; little quartz
10			6.4	2	10		Silty sand + gravel pebbles (<15mm); granules [illegible] coarse sand; dk-gray-brn; [illegible] subrounded to angular
15			9.2	3	15		Weathered basalt frags; blk, lt olive brn + dk olive gray + blueish frags (per driller - hit bedrock at 12')
20			11.2	4	20		Basalt; massive; blk; bluish coating on surface of some frags, some olive frags
25		3	1.2	5	25		Basalt; massive; blk, some dk olive gray + dk yel brown frags
30'		3	0.5	6	30		Basalt; massive, blk; trace quartz

added drill pipe

MW 1?

Borehole FT-1 Mod

Log of Borehole

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MW 158

Project FAIRCHILD AFB	Total Depth 91'	START FINI
Location FT-1 ~~pump~~ Mid pump Loc#3	Borehole Dia 8"	Date 10/3/91
Geologic Log by A. Cavazos, SAIC	Depth to Fluid 5'	Time 0940 152
Driller [illegible], [illegible]	Rig CP 7000	How Left Monitor
Geophysics by	Bit(s) 8" air rotary, 8" hammer bit	security box, [illegible]
Weather 70° Sunny	Fluid air water	

Time	Depth ft	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description
1033	35	~~.43~~	3	0.4	7	35		Basalt, massive, Black ~~trace~~, trace dk olive frags
1045	40	0.42	3	0.2	8	40		Basalt, massive, Black, trace dk olive gry frags
added drillpipe								
1105	45		3	0.4	9	45		Basalt; massive; black; trace dk ol frags
1119	50	0.36	3	0.3	10	50		Basalt; massive; black; trace dk olive gry coatings on some basalt frags; trace subang quartz grains
1134	55	0.33	3	0.2	11	55		Basalt; massive; black; trace dk olive gry frags; trace olive dk olive gry coatings on surface of Basalt frags.
1147	60	0.38	3	0.3	~~12~~ 5	60		Basalt; massive; blk; trace olive coating on surf of some basalt frags; ~~trace~~ subangular quartz grains
added drillstem @ ~63'								
1207	65		3	0.2	13	65		Basalt; massive; blk; trace olive to dk olive gry coating on surface of some bas. frags;

MW 158

Borehole FT-1 Mid

Log of Borehole

MW158

Project FAIRCHILD AFB	Total Depth 91'		START / FINISH
Location FT-1 Mid Pump	Borehole Dia 8"	Date	10/5/91 / 10/5
Geologic Log by A. Cavazos, SAIC	Depth to Fluid 5'	Time	0940 / 1522
Driller Louie Hanner, Ponderosa	Rig CP 7000	How Left	Mounted
Geophysics by	Bit(s) 8" air rotary, 8" hammer bit		security box - nole
Weather 70° Sunny	Fluid air water		

Time	Depth ft 0	Pene. Rate ft/min	Circulation Q (gpm)	HNu PPM	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description
1218	70	0.45	3	0.6	14	70		Basalt; massive; blk; trace olive + olive gray frags and coating on basalt frags.
1233	75	0.33	3	0.6	15	75		Basalt; massive; blk; trace olive coating on some basalt frags.
1246 Stopped for H2O; Stop 1250, start 1335; Added drill string 1340, 1344	80	0.38	3	0.2	16	80		Basalt; massive; blk; trace dk olive gray to translucent wht frags + coating on basalt frags
1350	85	0.33	3	0.0	17	85		Basalt; massive; blk; trace olive and translucent white coating on some basalt frags
1400	90	0.50	3	0.2	18	90		Basalt; massive; blk; trace olive and translucent wht coating on some basalt frags.

MW-159

Borehole FT-1 Corehole

Log of Borehole

page 1 of 6

Project FAFB MW-159	Total Depth 195	START / FINIS
Location FT-1 (Corehole Reamed)	Borehole Dia 10"	Date 102091 / 102291
Geologic Log by G DiGregorio	Depth to Fluid	Time 1331 / 1200
Driller Louie Hanner/Ponderosa	Rig CP 7000	How Left w/ locking
Geophysics by NA	Bit(s) Tricone Rollers percussion hammer	well monument in
Weather Clear 60°F, 5-10 mph	Fluid water	place

Depth	Pene. Rate/ ~~Blow Cts~~	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0	—	2	—				sand, clay coarse ang-subrnd qtz felds and basalt w/ FeOx staining; clay dark brown - gray stiff plastic	
5	—	2	—				sand and gravel, coarse, ang-subrnd ≤ 15mm, qtz felds and basalt w/ FeOx staining becoming more gravelly at depth	
10	—	2	—			Bedrock	Sand and gravel, coarse ang-subrnd ≤15mm, qtz, felds & basalt w/ minor FeOx staining. Bedrock @ 14'.	
15		2	—				Basalt dense fine grain w/ minor FeOx staining and fractures Fractures coated w/ $CaCO_3$ yellowish green and blue green mineralization Grayish blk N2	
20	30	2	—				Basalt, dense med-fine grain w/ minor basalt cuttings - ≤ 20mm weathered w/ FeOx staining grayish blk N2	
25	27.2	2	—				Basalt, dense med-fine grain fractures @ 27 and 29' w/ $CaCO_3$ coating grayish blk N2	
30	33.3	2	—				Basalt, dense med-coarse fractures w/ blk filling and $CaCO_3$ fractures @ 32 and 35' grayish blk N2	
	21.4							

Log of Borehole

Project FAFB	Total Depth 195	START / FINISH
Location FT-1 (Corehole) MW-159	Borehole Dia 10"	Date 102091 / 102291
Geologic Log by G. DiGregorio	Depth to Fluid	Time 1331 / 1200
Driller Louie Hamner / Ponderosa	Rig CP 7000	How Left with locking
Geophysics by	Bit(s) Tricone [illegible] & percussion hammer	well monument in
Weather Partly Cldy 55°F	Fluid water	place

Depth 35' ∅	Pene. Rate/ ~~Blow Cts~~	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
		2	–			^ ^ ^ ^	Basalt - dense med-fine grain w/ fracture from 37-40', blk coating w/ greenish blue tint. grayish blk N2	
40	25	2	–			^ ^	Basalt - Coarse grain, fractures - minor w/ blk coating. mineralization in basalt yellowish green grayish blk N2	
45	16.6	2	–			^ ^	Basalt coarse grain w/ mineralization yellowish green; fractures minor w/ CaCO3 filling [illegible]. grayish blk N2	
50	27.2	2	–			^ ^ ^	Basalt, coarse grain w/ mineralization yellowish green, fracture @ 53-55' w/ blk and ~~[illegible]~~ blueish coating grayish blk N2	
55	25	2	–			^ ^	Basalt, coarse grain w/ mineralization yellowish green minor fracture @ 55' CaCO3 filling, grayish blk N2	
60	27.2	2	–			^ vessicular ^ ^	Basalt, coarse grain, vessicular w/ mineralization yellowish green grayish blk N2	
65	21.4	2	-			^ ^ ^ ^	Basalt, coarse grain vessicular w/ mineralization yellowish green minor fractures @ ~~[illegible]~~ 60 69' grayish blk N2	
	30							

Borehole FT-1 Corehole

Log of Borehole

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Project FAFB MW-159	Total Depth 195	START / FINISH
Location FT-1 (corehole reaming)	Borehole Dia 10"	Date 102191 102291
Geologic Log by G. DiGregorio	Depth to Fluid	Time 1331 1206
Driller Lewis Hanner / Pendercrase	Rig CP 7020	How Left with locking
Geophysics by NA	Bit(s) Tricone roller & percussion hammer	well monument in
Weather Overcast 50°F, windy	Fluid water	place

Depth 70	Pene. Rate/ ~~Blow~~ ft/hr ~~Cts~~	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
		2	–			^ ^ ^	Basalt coarse grain vesicular to 72', becoming more dense w/ fracture calcite filling and blk - blue green coating, no vesicles grayish blk N2	
75	30	2	–			^ ^ ^	Basalt, dense medium-fine grain highly fractured w/ CaCO3 filling and blk to g blue green coating grayish blk N2	
80	25	2	–			^ ^	Basalt dense med-fine grain fractures to 83' w/ CaCO3 filling and blk to blue green coating grayish blk N2	
85	25	2	–			^ ^ ^ ^	Basalt med-fine grain w/ mineralization yellowish green, fractures w/CaCO3 filling Grayish blk N2	
90	23.0	2	–			^ ^ ^	Basalt dense med-fine grain w/ mineralization yellowish green minor fractures at 91-93 of CaCO3 filling Grayish blK N2	
95	~~21.4~~ 30	2	-			^ ^ ^	Basalt, dense med-fine grain w/ mineralization fractures throughout interval, some long w/ CaCO3 coating and blue green coating grayish blK N2	
100	21.4	2	–			^ ^ ^	Basalt dense fine grain of minor mineralization yellowish green minor fractures w/more @ 105 grayish blk N2	
	18.8							

Borehole FT-1 Gr[illegible]

Log of Borehole

page 4 of 6

Project EAFB MW-159	Total Depth 195	START FINISH
Location FT-1 (Combat Arms)	Borehole Dia 10"	Date 102191 102591
Geologic Log by G. DiGregorio	Depth to Fluid	Time 1331 1206
Driller Louis Hoover/Ponderosa	Rig CP 700	How Left with locking
Geophysics by NA	Bit(s) Tricone & percussion hammer	well monument in
Weather overcast, 50°F, windy	Fluid water	place

Depth	Pene. Rate/ ft/hr ~~Blow~~ cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
105		2	—			^ ^	Basalt dense fine grain w/ minor mineralization yellowish green, minor fractures at 105' w/ CaCO3 filling grayish blk N2	
110	25	2	—			^ ^	Basalt, dense fine grain w/ fractures greenish black to tan CaCO3 filling grayish blk N2	
115	17.6	2	—			^ ^	Basalt dense fine grain w/ major fractures at 116 - 119' blk coating and CaCO3 filling(minor) bluish green filling and blk coating grayish blk N2	
120	17.6	2	—			^ ^	Basalt dense medium grain w/ mineralization yellowish green, fractures minor w/ blk & bluish blk coating and coating grayish blk N2	
125	13.8	2	—			^ ^	Basalt, dense med-fine grain w/ minor mineralization yellowish-green, minor fractures w/ blk-bluish blk coating and tan CaCO3 filling Grayish blk N2	
130	25	2	—			^ ^	Basalt, dense fine grain w/ fractures, blk - bluish blk coating and tan CaCO3 filling grayish blk N2	
135	15	2	—			^ ^	Basalt dense medium grain w/ yellowish green mineralization, minor fracture w/ CaCO3 filling and bluish blk - blk coating - grayish blk N2	
	16.6							

Log of Borehole

Project FAFB MW-159	Total Depth 195	START / FINISH
Location FT-1 (Core coring)	Borehole Dia 10"	Date 102291 / 102291
Geologic Log by G. DiGregorio	Depth to Fluid	Time 1331 / 1230
Driller Louie Homer/Ponderosa	Rig CP7000	How Left with locking
Geophysics by N/A	Bit(s) Tricone roller & percussion hammer	well monument in
Weather Clear 55°F, windy	Fluid water	place

Depth	Pene. Rate ft/hr	Circulation Q (gpm)	OVA/HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
140		2	–			^ ^	Basalt, dense medium grain w/ yellowish green mineralization minor fractures w/ CaCO3 filling and blk - bluish blk coating	
145	15	2	–			^ ^	Grayish blk N2	
						^ ^	Basalt, dense hard fine grain w/ minor mineralization & minor fractures	
							Grayish blk N2	
150	18.7	2	–			^ ^ ^	Basalt, dense, hard, fine grain w/ mineralization and fractures CaCO3 filling yellow-tan and a green to greenish blue filling	
155	18.7	2	–			^ ^ ^	grayish blk N2	
							Dense massive basalt w/ minor fractures, fine grain, fractures contain minor CaCO3 filling and black coating, hard drilling	
160	11.5	2	–			^ ^ ^	Grayish blk N2	
							Basalt, dense massive fine-med grain, minor mineralization fractures minor w/ dark - bluish blk coating.	
165	12	2	–			^ ^ ^	Grayish blk N2	
							Basalt, dense massive, hard drilling, minor fracture at 167' w/ CaCO3 filling and yellowish-green coating	
170	12	2	–			^ ^ ^ ^	Grayish BlK N2	
							Basalt dense massive fine-med grain w/ minor mineralization minor hairline fractures w/ CaCO3 filling	
	8.6						Grayish BlK N2	

Borehole FT-1 Core hole

Log of Borehole

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Project FAFB MW-159	Total Depth 195	START / FINISH
Location FT-1 (core reaming)	Borehole Dia 10"	Date 102091 / 102291
Geologic Log by G. DiGregorio	Depth to Fluid	Time 1331 / 1200 Exit
Driller Louie Hauner / Ponderosa	Rig CP 7000	How Left with 12" well monument in place
Geophysics by N/A	Bit(s) Tricone ~~button~~ tab- & percussion hammer	
Weather Overcast windy 45F	Fluid water	

Depth 175 Ø	Pene. Rate/ ~~Blow Cts~~ ft/min	Circulation Q (gpm)	OVA/HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
		2	—			^ ^	Basalt, dense, massive w/ minor fractures, CaCO3 filling/ coating grayish blk N2	
180	10.7					^		
		2	—			^ ^	Basalt, dense, massive minor fractures w/ CaCO3 coating. grayish blk N2 ~~7D 8 184 80~~	
185	11.5					^ ^ ^		
		2	—			^ ^	Basalt, dense, massive grayish blk N2	
190	13.6	Z60						
		2	—			^ ^	Basalt, dense, massive w/ minor fractures and vessicles @ 193', CaCO3 filling, grayish blk N2	
195	11.5					^		

CORE DESCRIPTION

Borehole FT-1/MW-15

Log of Borehole

page 1 of 4

Project Fairchild AFB	Total Depth 230	START / FIN
Location FT-1 / MW-159	Borehole Dia 3"	Date 092791 / 100191
Geologic Log by Di Gregorio	Depth to Fluid	Time 0900 / 1400
Driller Tom Fisher / Boyles Bros.	Rig Mobile Drill 61	How Left
Geophysics by NA	Bit(s)	
Weather Sunny 70°F	Fluid water	

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample Run #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
15				1	15		Dense massive basalt. minor	
							vessicles 2-6mm and fractures	
							at 15.5-15.7' grayish blk N2	
20					19.25			85%
				2			Dense massive basalt with	
							minor vessicles < 4 mm, large	
							fracture (filled, waxy blk N1)	
							extends from 23-24.2'	
25				2	24.79			100%
				3			Dense massive basalt fractures	
							at 27.2' (filled, waxy) and	
							32.7 (calcium carbonate filled	
							white/yellow	
35					35.3			100%
				4			Dense basalt with fractures @	
							36.4', 38.55 (~~wax~~ mineralization)	
							39.7 (mineralization) 40.2 (waxy)	
							41.7 vessicular contact & coarser grain 1.5' thick	
45					46.4		occasional coarse grain streaks, 44.9 fracture (min) vessicular 45.1 →	
				5			vessicular basalt. Fractures @ 49.16	
							waxy & mineralization) 52.5, 53 (mineralization)	
						mineralization	53.6 and 54.15. Large vesicles and mineral	
							crystallization from 48.8-49.8 and 52.7-53.7	
55					54.7		grayish blk N2	100%
				6			Vessicular basalt < 1 mm	
65					64.7			100%
				7			Dense basalt. Fractures from 65.5-	
							67.4 w/ mineralization and 68.6-70	
							blk coating. Horizontal fractures w/ BLK	
							coating @ 71, 71.8, 72.5, 72.85, 73.9 &	
75							74.3' grayish blk N2	100%

Log of Borehole

Borehole FT-1

page 2 of 4

Project Fairchild AFB	Total Depth 230	START / FINISH
Location FT-1 / MW-159	Borehole Dia 3"	Date 092791 / 100191
Geologic Log by DiGregorio	Depth to Fluid	Time 0900 / 1400
Driller Tom Fisher / Boyles Bros.	Rig Mobile Drill 61	How Left
Geophysics by NA	Bit(s)	
Weather Sunny 70°F	Fluid water	

Depth 75	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
				8			Dense basalt w/ numerous hairline fractures throughout. grayish blk N2	
85								100%
				9			Dense basalt, fractures @ 86.5', 88.25', 89.8', ~~90.3~~ 90 grayish blk N2	
95								100%
				10			Dense basalt with fractures. Multiple horizontal hairline → low angle fractures open and tight. Grayish blk N2	
105								100%
				11			Dense basalt w/ numerous hairline low angle fractures, tight. Large fracture @ 111.75 (near vertical w/ mineralization) grayis blk N2	
115								100%
				12			Dense basalt w/ highly fractured zone near vertical 115.7-117, 119.6, 120-122 filling 2-3mm thick some waxy, grayish blk N2	
125								100%
				13			Dense basalt, curved fractures 128-129 vertical fracture, 132-134 near vertical fracture w/ 2-3mm filling	
135								100%
				14			Dense basalt, some curved fracture zones, 140.7-141 near vertical w/ filling 143.2-143.5 near vertical w/ filling grayish blk N2	100%

145

Log of Borehole

Project SAIC	Total Depth	START / FIN
Location FT-1 / MW-159	Borehole Dia	Date
Geologic Log by DiGregorio	Depth to Fluid	Time
Driller Tom Fisher, Jim Crill	Rig Mobile Drill 61	How Left
Geophysics by	Bit(s)	
Weather Clear 55°F	Fluid water	

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
150								
152.46			0/0				Dense, massive basalt grayish Blk, N2	20%
							Dense massive Basalt, grayish Blk	
							N2. Large fracture at 153.66	
							extending to 154.36' waxy w/ minor	
160.06							mineralization grayish yellow 5Y 8/4	100%
	Run #18 to 167.11'						Dense, massive basalt grayish blk	
		7.05' loss 2' core GD					N2, high fractures from 165.36	
			0/0				to 167.11. Fractures w/ minor	~~100%~~ 73
							mineralization and waxy	100%
GD ~~170~~ ~~169~~ 167.11								
			0/0				massive dense basalt w/ minor	
							fractures. 6.3' recovery grayish Blk	100%
175.~~3~~46 GD			loss 2' core				N2. Fractures @ ~~172.5'~~ ~~174.6'~~ 170.6' & 172.7'	
		Recovered on next run						
180								
							massive basalt, dense with fractures	
183.6		End of Run #20					at 175.3-177.3, 177.5 and	
			0/0				178.9' Grayish blk N2	100%
		End of Run #21					Dense massive basalt no fractures	
185 ~~140~~			0/0				grayish blk N2 1.4'	100%
							massive dense basalt no	
1		End run # 22					fractures grayish blk N2	100%
			0/0					
190 ~~200~~								
							Dense massive basalt	
		Run # 23					large mineralized fracture at	
			0/0				190' not broken grayish blk	
							N2	
195								100%
		Run #24					Massive dense basalt Grayish	
							blk N2 199.62'	100%
			0/0					
200								

Borehole FT-1

Log of Borehole

Project SAIC / Fairchild AFB	Total Depth		START / FINISH
Location FT-1 / MW-159	Borehole Dia	Date	
Geologic Log by DiGregorio	Depth to Fluid	Time	
Driller Tom Fisher .. Boyles Bros.	Rig Mobile Drill 61	How Left	
Geophysics by	Bit(s)		
Weather overcast 60°F	Fluid water		

Depth	Pene Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU Hole/Rig	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
200							massive dense basalt to 202.5'	100%
		Run #25 length of					becomes more vessicular. from 203.5–	
		core 4.98'					204.6 large fracture w/ tan & turquois	
							clay stone and sugar coating mineralization	
205							greyish blk N2 – 204.60 –	
							vessicular basalt to 206.45, 2-4mm	
							inter flow A contact clay & wood chips	
		End Run #26 - 4.6'					weak greyish brown w/ fractures from 206.45 –	
							207.85 ye 5YR 3/2. Grading to black N1	
210	(208.6)						fracture w/ mineralization breccia (multi colored)	100%
							clay stone greyish brown w/ minor	
							fractures grading to black 5YR 3/2 –	
							N1 – wood chips and organic material	
		Run #27 2.86'					throughout [illegible]	75%
215		Run #28 1.5'						
							Claystone blk N1 w/ wood chips	
							from 215–215.4 grades to greyish clay	
		Run # ~~28~~ 29					no organics to 215.7. Flow B contact at	5B 3/6
							215.7. Highly vessicular basalt w/ 2-12mm	
220							minor fract @ 216.5 – 220 (highly fract)	100%
		Run # 30					vessicular basalt 15-[illegible] mm	
							mineralization / sugar coating	
							fractures @ 221.5' 223.4'	
							highly fractured w/ minor weathering	
225							from 222.3 – 223 light blue clay 5B 6/[illegible]	100%
							vessicular basalt 15-20mm	
							w/ mineralization / sugar coating	
230								100%

BORING LOG

NUS CORPORATION

PROJECT: FAFB

BORING NO.: MW 159

PROJECT NO.: 3286

DATE: 9-91

DRILLER: BOYLES BROS.

ELEVATION:

FIELD GEOLOGIST: SJ CONTI

WATER LEVEL DATA:

(Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY/ SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/ft.)	MATERIAL DESCRIPTION*: SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR. OR USCS	REMARKS
	0.0								
									0-160 - NOT
									LOGGED BY NUS
									SEE SAIC LOG
									FOR DETAILS.
	5.0								
	10.0								
	15.0								START TO CORE @15'
	1								
	20.0								
	25.0								

REMARKS NX SIZE CORE HOLE (3" Φ HOLE)

MOBILE B61 RIG

BORING MW 1

PAGE 1 OF 1

* See Legend on Back

BORING LOG | **NUS CORPORATION**

PROJECT: FAFB BORING NO.: MW159
PROJECT NO.: 3286 DATE: 9-91 DRILLER: BOYLES BROS
ELEVATION: FIELD GEOLOGIST:
WATER LEVEL DATA :
(Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY / SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/ft.)	MATERIAL DESCRIPTION* SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR. OR USCS	REMARKS
	25.0								
	50.0								

REMARKS

BORING MW 159

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* See Legend on Back

NUS CORPORATION

BORING LOG

PROJECT: FAFB
PROJECT NO.: 3286
DATE: 9-91
BORING NO.: MW 159
DRILLER: BOYLES BROS.
ELEVATION:
FIELD GEOLOGIST:
WATER LEVEL DATA:
(Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/ft.)	MATERIAL DESCRIPTION* SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR. OR USCS	REMARKS
	50.0								
	75.0								

REMARKS

BORING MW

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* See Legend on Back

BORING LOG — NUS CORPORATION

PROJECT: FAFB — BORING NO.: MW 159
PROJECT NO.: 528C — DATE: 9-91 — DRILLER: BOYLES BROS
ELEVATION: — FIELD GEOLOGIST:
WATER LEVEL DATA:
(Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (Ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY / SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/Ft.)	MATERIAL DESCRIPTION*: SOIL DENSITY/CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR. OR USCS	REMARKS
	75.0								
	100.0								

REMARKS

BORING MW 159

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* See Legend on Back

BORING LOG

NUS CORPORATION

PROJECT: FAFB

BORING NO.: MW159

PROJECT NO.: 3286

DATE: 9-91

DRILLER:

ELEVATION:

FIELD GEOLOGIST:

WATER LEVEL DATA :

(Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY / SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.)	MATERIAL DESCRIPTION* SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR. OR USCS	REMARKS
	100								
	125.0								

REMARKS

BORING MW 1--

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* See Legend on Back

BORING LOG NUS CORPORATION

PROJECT: EAFB BORING NO.: MW 159

PROJECT NO.: 3286 DATE: 9-91 DRILLER: BOYLES BROS

ELEVATION: FIELD GEOLOGIST:

WATER LEVEL DATA:

(Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.)	MATERIAL DESCRIPTION* SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR. OR USCS	REMARKS
	125								
	150.0								

REMARKS

BORING MW 15

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* See Legend on Back

BORING LOG NUS CORPORATION

PROJECT: EAFB
PROJECT NO.: 3286
ELEVATION:
DATE: 9-30-91
FIELD GEOLOGIST: S CONTI
BORING NO.: MW 159
DRILLER: BOYLES BROS.
WATER LEVEL DATA: (Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/ft.)	SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR. OR USCS	REMARKS
					M HARD TO HARD	GRAY	BASALT		SJC BEGING TO LOG HOLE ALONG W/ SAIC ON 9-30-91
									THIS WAS A GENERALIZED LOG FOR DETAIL SEE SAIC LOG.
	155.0								
	160.0							BL	
					M HARD TO HARD	GRAY	BASALT	TO M	162.0 → 162.6 FRACTURES (HI 4)
	(18)	73%	100%						
								BR	165.3 – 167.1 VBR TO BR
								VBR	
	167.1								
								BL	170.5 LO4 FRACTURE
	(19)	100%	100%						172.6 → 173.0 HI4 FRACTURE
	175.3								

REMARKS

BORING MW 1[illegible]

PAGE 1 OF 1

* See Legend on Back

BORING LOG	NUS CORPORATION

PROJECT: FAFB BORING NO.: MW 159
PROJECT NO.: 3286 DATE: 9-30-91 DRILLER: BOYLES BROS
ELEVATION: FIELD GEOLOGIST: SJ CONTI
WATER LEVEL DATA:
(Date, Time & Conditions)

	SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.)	MATERIAL DESCRIPTION* SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR. OR USCS	REMARKS
		175.0				M HARD TO HARD	GRAY	BASALT	BL	175.3 → 177.0 VERT FRACTURE
										177.5 LO∠ FRACTUR
		20	100%	100%						
										179 → 181± BREAKS WHILE REM. OF CORE
9-30		183.6								
10-1		21	100%	100%						183.9 LO∠ FRACTURE
		185.0								
									M	ALL SOLID PC. SAVE FOR TIGHT FRACTURE @ 187±
	0850	22		100%						
		190.0							M	AT 190 HI∠ INTACT FRACTURE
	0910	23	100%	100%						
		195.0							M	
	0935	24		4.7/5.0						
		200.0								

REMARKS

BORING MW 15
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* See Legend on Back

BORING LOG | **NUS CORPORATION**

PROJECT: FAFB | BORING NO.: MW 159

PROJECT NO.: 3286 | DATE: 10-1-91 | DRILLER: BOYLES BROS

ELEVATION: | FIELD GEOLOGIST: SJ CONTI

WATER LEVEL DATA :

(Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY - SAMPLE LENGTH	LITHOLOGY CHANGE (Depth, ft.)	SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR OR USCS	REMARKS
	200.0				M HARD	GRAY	BASALT	M	
					TO HARD				
1050	25	100/100%	100%						203 - ? MORE VESICULAR
								BL	203.9 → 204.4 HI ∠
									FRACTURE VUG SOME BRN-MATL IN
	205.0								
								BL	FRACTURE ZONE. MORE 206.6 → 206.9 VESICULAR
				206.9					206.9 CONTACT BETWEEN ZONE A BASALT AND
1130	26	1.8/5.0	4.6/5.0	208.3	MSOFT	GRAY BRN	CLAYSTONE - SILTY	BR	INTERBED 207.3, 207.4, 207.6, 207.
						TO BLK	CARB/ORG CLAYSTONE		LOW ∠ FRACTURES 208.3 [illegible] DARK
	210.0					BRN	(SILTY)		GRAY - BLK BRN ORGANIC APPEARANCE
				211.0					FROM 208.3 TR. OF WOOD.
1150	27	2.3/3.0	2.9/3.0	INTERBED		GRAY BRN	CLAYSTONE - SILTY		210.8 HORIZ FRACT.
									212.0 FRACTURE ZONE WOOD FRAGS
	213.0								FEW VUG ZONES THRU-OUT
1205	28	1.3/2.0	1.5/2.0			BLK BRN			≈213.9 - BECOMES DARKER W/ HORIZ FRACTURE
	215.0			215.4					TR. WOOD FRAG
					M HARD TO HARD	BLUE GRAY	BASALT	BL	TOP OF B FLOW HIGHLY VESICULAR L
1240	29	4.0/5.0	4.9/5.0						NUMEROUS VUGS TO 220.0
									216.5 } HORIZ FRACTURE 217.5 } (GREENISH CO
								BR	219 ≈ BECOMES BRO 220.2 HORIZ FRACTURE
	220.0							BL	STILL NUMEROUS VUGS TO 225.0
1300	30	4.9/5.0	4.8/5.0						VERT 222.5-222.9 FRACTURE
								BR	223.0 BR (GREENISH)
									223.4 HORIZ FRACTURE
	225.0								

REMARKS INTERBED ≈ 8.5' THICK. 206.9 → 215.4

BORING MW 159

* See Legend on Back

BORING LOG	NUS CORPORATION

PROJECT: FAFB
PROJECT NO.: 3286 DATE: 10-1-91
ELEVATION: FIELD GEOLOGIST: CONTI
BORING NO.: MW 159
DRILLER: BOYELS BROS
WATER LEVEL DATA:
(Date, Time & Conditions)

SAMPLE NO. & TYPE	DEPTH (ft.) OR RUN NO.	BLOWS 6" OR RQD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (Depth/ft.)	MATERIAL DESCRIPTION* SOIL DENSITY/ CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	ROCK BR OR USCS	REMARKS
	225.0				M HARD TO	BLUE	BASALT	BR	
					HARD	GRAY			
1320	31								
	230.0			230					
							Bottom 230.0'		

REMARKS

BORING MW 15
PAGE 10 OF 15

* See Legend on Back

MW 160

Borehole ~~ST-1~~ ~~Loc~~ ~~[illegible]~~

Log of Borehole

MW160

Project Fairchild AFB	Total Depth 40'		START / FINISH
Location FT-1 ~~[illegible]~~ Obs #2 Loc 4/L	Borehole Dia 8"	Date	10/16/91 / 10/17/91
Geologic Log by A. Cavazos, SAIC	Depth to Fluid	Time	1400 / 1700
Driller Alvin Carrie, Ponderosa	Rig CP 650	How Left	~~Surface~~ Security monument installed w/ lock
Geophysics by	Bit(s) 8" tricone, 8" reamer bit		
Weather 50' windy, Gusty	Fluid air, water		

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0								
							at 4½	
5								
							Sand; medium sand; yelsh brwn to	
							well sorted; subrounded; at 5' Basalt; weathered;	
							blackish red (5R 2/2)	
							(per driller - hit ~~[illegible]~~ at 5'3; hit softer rk then	
							hard rk again at 9') Basalt is mixture of weathered [illegible] w/ yel brown coating + [illegible] gry [illegible]	
10							Basalt; some weathered, subangular basalt frags	
							some dense basalt angular frags; dk gry (N3) and blackish red	
							(5R 2/2).	
15								
							Basalt; weathered basalt frags w/ iron oxide coating	
							and dense basalt, some silt Blackish red (5R 2/2) to	
							dark gray (N3)	
							(per driller fracture zone 17'-17½')	
20							Basalt; weathered and dense basalt fragments ground	
							to sand size by bit; little silt. Blackish red (5 Y 2/2)	
							dk gry (N3)	
							(per driller - soft zone at 24'-25½')	
25							Basalt; mostly weathered and some clean; blackish	
							red (5 Y 2/2) to dk gry (N3); Larger frags up to 30 mm	
							Iron oxide staining and mineralization on surface of	
							siliceous filling; basalt coating on frag	
30							Basalt; massive, some weathering; greenish black (5 G 2	
							to grayish brown (5 YR 3/2) and blkish red (5 Y 2/2);	

MW 160

Borehole FT-1 Loc 416

Log of Borehole

page 2 of 2

Project Fairchild AFB	Total Depth 40'	START FINISH
MW160 Location FT-1 Loc 416 (Shed Cas #2)	Borehole Dia 8"	Date 10/16/91 10/17/91
Geologic Log by A. Cavazos, SAIC	Depth to Fluid	Time 1400 1700
Driller Alvin Carris Ponderosa	Rig CP 650	How Left Surface
Geophysics by	Bit(s) 8" Tricone roller, 8" hammer bit	monument installed w/
Weather	Fluid air, water	lock

Depth	Pene. Rate/ Blow Cts	Circu-lation Q (gpm)	OVA/ HNU	Sample #	Sample Inter-val	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
35							Basalt; massive, greenish blk (5G 2/1); trace olive gray (5Y 4/1) coating on some frags.	
40							Basalt; massive; greenish blk (5G 2/1); trace olive gray (5Y 4/1) coating on frags.	

Borehole MW161

Log of Borehole

page 1 of 2

Project FAFB	Total Depth ~~44.2~~ 48'	START / FINISH
Location FT1 (Loc 7) MW161	Borehole Dia 8"	Date 15Oct91
Geologic Log by N. Garrister / G. DiGregorio	Depth to Fluid	Time 0700
Driller Ponderosa Alvin Corris	Rig CP-650	How Left
Geophysics by —	Bit(s) 8" tricone / 7 7/8" hammer	
Weather clear 60-70	Fluid Water	

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0								
5							(gm) sand- angular, c-m+, silt and some f grvl 5YR 5/2	
							(sp) sand- poorly graded subang & rounded to fines 5Y 5/2 - 5Y 3/2 - 5YR 4/2	
10							Basalt- dense hard minor fractures with filling some FeOx staining	
15							Basalt, medium grain, vessicles at 16' ~3mm. Fractures from 16-20' with black waxy surfaces and mineralization (light greenish yellow CaCO3 concreations) N2 dark grayish blk	
20							Basalt, medium to coarse grain, vessicles and fractures at 22-23' becomes dense. Fractures filled w/ greenish-yellow CaCO3. N2 grayish blk	
25							Basalt, dense, coarse grain minor fracture at 29-30' w/ CaCO3 filling	
30							Basalt, dense, coarse grained minor fracture at 32' w/ CaCO3 filling grayish blk N2	

Borehole MW 161

Log of Borehole

page 2 of 2

Project FAFB	Total Depth ~~44.5'~~ 48'	START FINISH
Location FT-1 (Loc 7) MW161	Borehole Dia 8"	Date 101591 101591
Geologic Log by N. Ganister / G. DiGregorio	Depth to Fluid	Time 0700 1535
Driller Alvin Carris / Pendergrass	Rig CP 650	How Left
Geophysics by N.A	Bit(s) 8" tricone / 7 7/8 Percussion hammer	
Weather Clear 70	Fluid water	

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
35						^ ^	Basalt dense coarse grain	
						^ ^	minor fracture at 40' w/ $CaCO_3$	
							filling and black waxy filling. Softer	
						^ ^ ^	drilling at 40'	
40						^		
							Basalt, dense coarse grained;	
						^ ^	fracture at 40' -- 42' w/	
						^	black waxy surfaces and black mud	
						^	TD at 44'	
45							continue drilling	
						^ ^		
						^	46'-47' slight fracture zone,	
						^ ^	some weathering and discoloration	
						48	TC gray no mineralization	
50							observed.	
							TD at 48'	

MW-162
MW-163
Borehole FT-1 obs #2

Log of Borehole

Project: Fairchild AFB	Total Depth 190	START / FIN
Location G. AW FT-1 OBS #2 (MW-162)	Borehole Dia 10"	Date 101491 / 101891
Geologic Log by G. DiGregorio	Depth to Fluid	Time 1602 / 14—
Driller Louie Hasnel / Ponderosa	Rig CP 7000	How Left w/ lid +
Geophysics by NA	Bit(s) Tricone Roller & Percussion Hammer	steel monument
Weather Sunny 70°F	Fluid Water	

Depth	Pene. Rate/ ft/hr ~~Blow Cts~~	Circulation Q (gpm)	~~OVA~~/ HNU ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0			0				sand and gravel ≤ 20mm coarse sand subrnd basalt qtz and felds. Water at 3' clay minor d GC	
5		2	0		5		basalt gravel and sand, ≤ 12mm coarse, subang - subround qtz and feldspars. Basalt at 10' GC	
10		2	0		10	Bedrock	Basalt dense medium grain Fractures at 14.5 - 15'. mineralization greenish - yellow	
15		2	0		15		Basalt, coarse grain w/ minor mineralization. Drill break at 19-20' Greenish yellow	
20		2	0		20		Basalt coarse grain, fractures and vesicular to 22.5'. vesicles ≈ ~~7~~ 60 5mm large cuttings 40mm. Grades back to coarse grain Basalt to 25'	
25	21.7	2	0				Basalt coarse grained, minor fractures and FeOx staining some mineralization.	
30	38.5	2	0			Fractures	Basalt coarse grained, fractures at 33' to 35' w/ calcium filling. minor FeOx	
	31.3	2	0					

HNu background - 0.0 ppm

Borehole FT-1 [illegible]

Log of Borehole

Project: Fairchild AFB
Location: FT-1
Geologic Log by: G. DiGregorio
Driller: Louie Hennel / Pendleton
Geophysics by: NA
Weather: Clear 45°F

Total Depth: 190
Borehole Dia: 10"
Depth to Fluid: 3'
Rig: CP 7000
Bit(s): Tricone Roller & Hammer
Fluid: water

	START	FINISH
Date	101491	101891
Time	1602	1406
How Left:	w/ locking steel monument	

Depth 35 Ø	Pene. Rate/ ft/hr ~~Blow Cts~~	Circulation Q (gpm)	~~OVA/~~ HNU ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
						Fractures	Basalt, coarse grained, fractures with CaCO3 filling throughout 5' interval. Soft drilling from 37-40'	
40	33.3	2	0				Basalt, medium grained with minor fractures. Grayish blk N2	
45	17.9	2	0				Basalt, medium grained with mineralization in the matrix light green no noticeable fractures grayish blk N2	
50	31.25	2	0				Basalt, medium grained dense grayish blk N2	
55	18.5	2	0				Basalt coarse grain, fractured weathered w/ FeO2 staining, minor vesicles at 56'	
60	41.6	2	0				Basalt fractured, coarse grain minor FeO2 staining, CaCO3 filling, black waxy coating Soft drilling at 63'	
65	22.7	2	0				Dense basalt, coarse grain, minor fractures at 69-70' w/ CaCO3 coating	
	31.25	2	0					

NW-162/MW-1

Borehole FT-1 ~~085. LST~~

Log of Borehole

Project: FAFB	Total Depth 190		START / FI
Location FT-1	Borehole Dia 10"	Date	10/14/91 / 10/14/91
Geologic Log by G. DiGregorio	Depth to Fluid	Time	1102 / 1412
Driller Louie Hannel / Ponderosa	Rig CP 7000	How Left:	w/ locking steel monument
Geophysics by NA	Bit(s) 10" tricone roller & percussion hammer		
Weather Clear 70°F	Fluid water		

Depth 70 ø	Pene. Rate/ ft/hr ~~Blow Cts~~	Circulation Q (gpm)	~~OVA/~~ HNU ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
						^ ^ ^ ^ ^ ^	Basalt medium grain fractured throughout interval, $CaCO_3$ filling grayish blk N2	
75	22.7	2	0			^ ^ ^ ^ ^	Basalt medium grain, minor fractures to 78' becomes more dense grayish Blk N2	
80	31.25	2	0			^ ^ ^	Basalt, medium grain fractures throughout w/ $CaCO_3$ filling grayish blk N2	
85	23.8	2	0			^ ^ ^ ^	Basalt medium grain w/ $CaCO_3$ filled fractures throughout the interval grayish blk N2	
90	38.5	2	0			^ ^ ^ ^ ^	Basalt medium - fine grain w/ fractures @ 93-94', $CaCO_3$ filling minor fractures at 95 grayis blk N2	
95	21.7	2	0			^ ^ ^ ^ ^	Basalt, medium - fine grain w/ fractures at 96-99' BGS $CaCO_3$ filling, grayish blk N2	
100	31.8	2	0			^ ^ ^ ^ ^	Basalt, dense fine grain fracture at 102' w/ $CaCO_3$ filling minor fractures @ 104-105 grayish blk N2	
	38.5	2	0					

MW-162 / MW-1?

Log of Borehole

Borehole FT-1 [illegible]

page 4 of 4

Project: F.AFB	Total Depth: 190		START / FINISH
Location: FT-1	Borehole Dia: 10"	Date	10.1491 / 10.1591
Geologic Log by: C. DiGregorio	Depth to Fluid:	Time	1603 / [illegible]
Driller: Louie Hammil / Ponderosa	Rig: CP 7000	How Left:	w/ locking
Geophysics by: NA	Bit(s): 10" Tricone (collar) Percussion Hammer		well monument
Weather: over-cast 60°F, very windy	Fluid: water		

Depth (ft)	Pene. Rate/ ft/hr	Circulation Q (gpm)	HNU ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
110	33.3	2	0			^ ^	Basalt, dense fine grain with minor fractures throughout the interval, $CaCO_3$ filling, grayish blk N2	
115	45.5	2	0			^ ^	Basalt dense fine grain with minor fractures at 112', grayish blk N2	
120	18.5	2	0			^ ^	Basalt, dense fine grain, minor small fractures at 116' and 119', grayish blk N2	
125	18.5	2	0			^ ^	Basalt, dense tight fine grain. Fracture @ 124' w/ [illegible], filling, grayish blk N2	
130	21.7	2	0			^ ^	Basalt, dense tight fine grain w/ minor fracture @ 129' grayish blk N2	
135	14.3	2	0			^ ^	Basalt, dense very hard fine grain, fracture at 131 and 135' grayish blk N2	
	17.9	2	0			^ ^	Basalt dense very hard fine grain. drilling break at 139' medium grain, fractures grayish blk N2	

Borehole FT-1 [illegible]

Log of Borehole

Project: EAFB	Total Depth 190	START / FIN
Location: FT-1	Borehole Dia 10"	Date 121491 / 121191
Geologic Log by G. DiGregorio	Depth to Fluid	Time 1602 / 1406
Driller Louie [illegible] / Ponderosa	Rig CP 700	How Left: w/ locking steel monument
Geophysics by NA	Bit(s) 10" tricone roller & percussion hammer	
Weather overcast, cold 35°F	Fluid water	

Depth	Pene. Rate/ ~~Blow~~ ~~Cts~~ ft/hr	Circulation Q (gpm)	~~OVA/~~ HNU ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
140						^ ^	Dense basalt, medium-fine grain, fractures @ 141 and 144' grayish blk N2	
145	11.1	2	0			^ ^	Basalt dense medium-fine grain, minor hairline fracture w/ CaCO3, grayish blk N2	
150	14.3	2	0			^ ^	Basalt, dense medium-fine grain minor fracture w/ CaCO3 filling. more fractured @ 154' w/ CaCO3 filling & FeOx staining grayish blk N2	
155	11.6	2	0			^ ^	Basalt, dense medium-fine grain fractures w/ CaCO3 filling and greenish blk discoloration grayish blk N2	
160	8.9	2	0			^ ^	Basalt, dense fine grain w/ fractures throughout; filling scm at some spots, greenish blk coloring. grayish blk N2	
165	11.1	2	0			^ ^	Basalt fine grain, fractured w/ CaCO3 filling (thin) and greenish blue coating some FeOx staining, grayish blk N2	
170	18.5	2	0			^ ^	Basalt, med-fine grain, fractured w/ greenish clay and tr CaCO3 filling, clay mottled, grayish blk N2	
	11.6	2	0			^ ^		

MW-162 / MW-[illegible]

Borehole FT-1 [illegible]

Log of Borehole

Project: FAFB	Total Depth: 190	START / FINISH
Location: FT-1	Borehole Dia: 10"	Date: 101491 / 101?91
Geologic Log by: G. DiGregorio	Depth to Fluid:	Time: 1602 / ~~[illegible]~~ 1615
Driller: Louie Hanel / Ponderosa	Rig: CP 7000	How Left: w/ locking
Geophysics by: NA	Bit(s): 10" tricone rollers; percussion hammer	steel monument
Weather: partly cloudy 50°F	Fluid: water	

Depth	Pene. Rate/ ~~Blow Cts~~	Circulation Q (gpm)	~~OVA/~~ HNU ppm	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
175						^ ^	Basalt, dense, med-fine grain	
						^	minor fractures @ 175-177	
							more fractures at depth, $CaCO_3$	
						^ ^	filling, greenish blue coating and	
180	10.4	2	0			^	dark blk coating; grayish blk N2	
						^	Basalt dense fine grain	
						^ ^	hard. Minor fractures w/ $CaCO_3$	
							filling	
						^ ^	~~TD @ 189' BGS~~ GD	
185	11.9	2	0					
						^ ^	Basalt dense fine grain	
						^	minor fractures filled w/ $CaCO_3$	
						^	grayish blk N2	
190		2	0			^ ^	TD @ 190'	

MW164
Borehole SW-1 ~~loc 14~~

Log of Borehole

page 1 of 1

Project FAIRCHILD AFB	Total Depth 20'		START / FINISH
Location SW-1 ~~loc 14~~ MW164	Borehole Dia 6"	Date	9/23/91 / 9/23/91
Geologic Log by Chuck Houck SAIC	Depth to Fluid	Time	1330 / 1500
Driller PONDEROSA - Lonie Hamm	Rig CP780	How Left	~~pre-measured~~ P:
Geophysics by	Bit(s) 8" tricone - 8" hammer bit		~2.5 AGS - grout
Weather 65°, sunny, breezy	Fluid AIR / WATER		to surface. Secured temp pl.

	Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
	0								
			Ø	Ø	1	4.0			
			Ø	Ø	2	4.5			
1347	5							Silt, some fine sand, lt olive brown 5Y 2.5/4 dry	*
								Basalt - ~~fr~~ weathered/fractured - dry @ 4.5'	
1418	10		2	6	3	10		Basalt - massive - hard, black 2/0	2.5y
								"Softer" - driller - weathered frag.	
1424	15		2	5	4	15		Basalt - massive - hard, black 2/0	2.5y
1431	20		2	~~8~~ 3.6	5	20		Basalt - ~~mo~~ fractured - some weathered frags.	
								Driller ~~says~~ very hard "weathered" is probably dough	
								TD - 20'	

* Driller measured depth

Borehole WW1 - MW121

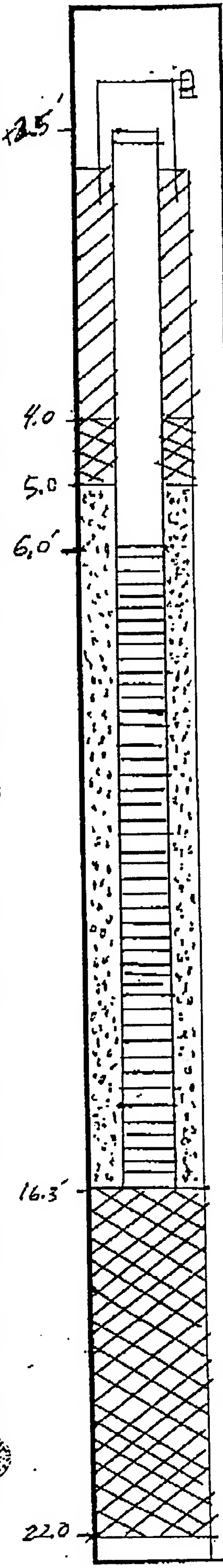
Log of Borehole

page 1 of 1

Project FAIRCHILD AFB, WA	Total Depth 22'	START / FINISH
Location FT1 - MW121	Borehole Dia 8"	Date 1/26/91 1/26/91
Geologic Log by J. Moore	Depth to Fluid 7.8' bgs	Time 1040 1548
Driller Alvin Corris	Rig CP650	How Left
Geophysics by NA	Bit(s) Tricone / Percussion hammer	
Weather partly cloudy mid 20's	Fluid water	

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0			B: 0.2 ppm				0-2: Topsoil v. fine gr. sand/silt	
			H: 0.2				organic 10YR 3/3 dk brown (OL)	
							2-5: sand silt gravel mix	
							10YR 5/3 brown (GM)	
10							5-10 - same as 2-5'	
							w/ boulder size basalt	
							10-15 dark gray basalt w/ FeOx fractures	
							staining fine grained 2-8mm frags	
							moist water at the unconsolidated/basalt contact	
20							15-20 hard dense angular dk gray	
							basalt fragments w/ minor FeOx	
							20-22 same as 15-20	
							H_2O present in bore hole in the	
							am 1/27 ~10' bgs.	
30							TD @ 22.0'	

Well Construction Summary



Location: FTI - MW121

Personnel: J. Moore

Elevation: Ground Level ______

Top of Casing ______

DRILLING SUMMARY:

Total Depth 22.0

Borehole Diameter 8"

Driller Alvin Carris w/ Ponderosa Drilling

Rig CP 650

Bit(s) Tricone / Percussion hammer

Drilling Fluid Water (minor)

Surface Casing No

WELL DESIGN:

Basis:

Geologic Log ✓ Geophysical Log ___

Casing String(s): C=Casing S=Screen

C1 +2.5 - 6.0

S1 6.0 - 16.3

Casing: C1 PVC Sch 80 (4" dia)

C2 ______

C3 ______

C4 ______

Screen: S1 Stainless Steel 0.01 slot

S2 ______

S3 ______

S4 ______

Centralizers NO

Filter Material Colorado Silica Sand 10-20 (3 bags)

Cement Portland Type I/II (4 bags)

Other 3/8" bentonite pellets (3½ buckets - 5 gal) ¼ bag Quick Gel

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	1/26/91	1040	1/26/91	1543
Geophys. Logging:				
Casing: Pvc & Screen	1/27/91	1019	1/27/91	1021
Filter Placement:	1/27/91	1127	1/27/91	1140
Cementing:	1/27/91	1214	1/27/91	1218
Bentonite Seal:	1/27/91	1141	1/27/91	1146
Other:				

Comments: H2O level @ 7.8'

Key:

- Bentonite
- Sand
- Cement/Grout
- Silt
- Sand Pack
- Clay
- Drill Cuttings
- Screen
- Gravel

Borehole WWI-MW123

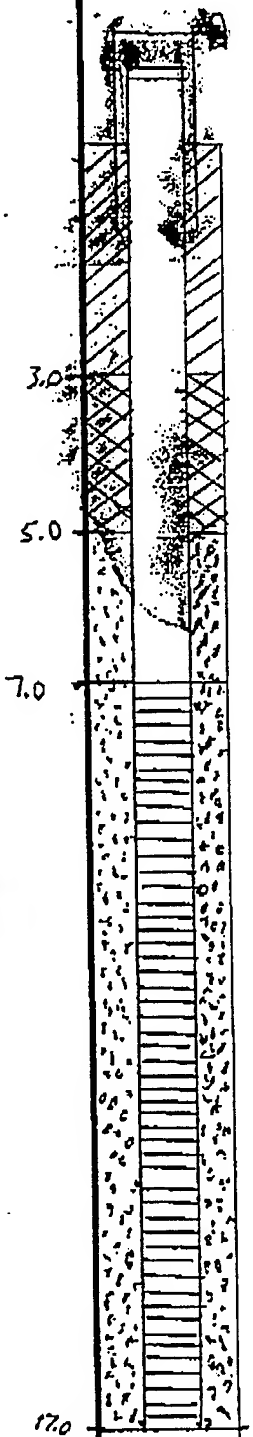
page 1 of 1

Log of Borehole

Project FAIRCHILD AFB, WA	Total Depth 17.0'		START / FINISH
Location FTI - MW123	Borehole Dia 5"	Date	1/21/91 / 1/27/91
Geologic Log by J Moore	Depth to Fluid	Time	0915 / 1105
Driller Alvin Carris	Rig CP 65C	How Left	
Geophysics by NA	Bit(s) Tricone / [illegible]		
Weather Clear Cold ~ 20°F	Fluid water		

Depth	Pene. Rate/ Blow Cts	Circulation Q (gpm)	OVA/ HNU	Sample #	Sample Interval	Lith. Symbol	Geologic and Hydrologic Description	% Core Recovery
0			B: 0.2 ppm				0-2': Topsoil v. fine gr silt	
			H: 0.2 ppm				organic rich 10YR 3/3	
							dark brown (OL)	
							2-5.5 Sand-silt gravel mix	
							10YR 5/3 brown (GM)	
10							5.5-10' dark gray hard	
							basalt frags <2 mm diameter	
							minor FeOX mixed w/ sand (minor)	
							10-15 dark gray, hard angular	
							basalt frag 2-8 mm) w/ minor sand from above	
20							15-17' dark gray hard angular	
							basalt frags TD	

Well Construction Summary



Location: FTI - MW123 Elevation: Ground Level ______

Personnel: J. Moore Top of Casing ______

DRILLING SUMMARY:

Total Depth 17.0' ±

Borehole Diameter 5.0"

Driller Alvin Chris
Ponderosa Drilling

Rig CP #650

Bit(s) Tricone/Percussion

Drilling Fluid Water (minor)

Surface Casing N/A

WELL DESIGN:

Basis:
Geologic Log ✓ Geophysical Log ___

Casing String(s): C=Casing S=Screen

C1	+3.0	7.0
S1	7.0	17.0

Casing: C1 PVC Sch 80 (4" dia)
C2
C3
C4

Screen: S1 Stainless Steel 0.01"
S2
S3
S4

Centralizers yes 1' above the screen

Filter Material Colorado Silica Sand 10-20

Cement Portland Type I/II

Other 3/8" Bentonite Pellets

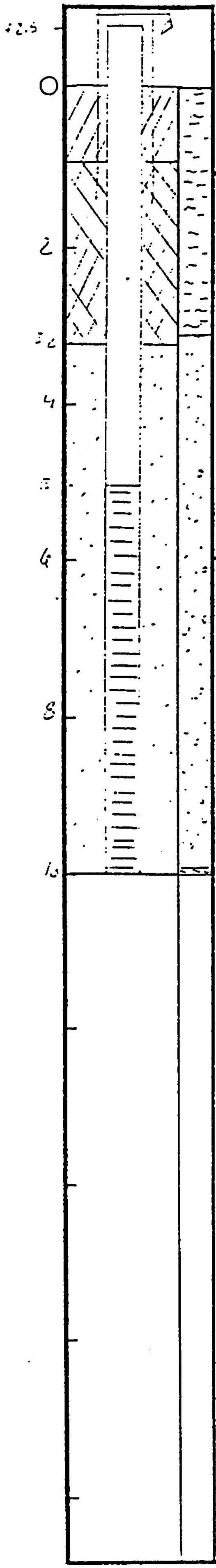
CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	1/28/91	910	1/28/91	1100
Geophys. Logging:				
Casing:	1/28/91	1317	1/28/91	1317
Filter Placement:	1/28/91	1343	1/28/91	1342
Cementing:	1/28/91	1403	1/28/91	1413
Bentonite Seal:	1/28/91	1343	1/28/91	1346
Other:				

Comments: H_2O @ 8.5'

Key:

- Bentonite
- Cement/Grout
- Sand Pack
- Drill Cuttings
- Gravel
- Sand
- Silt
- Clay
- Screen



Well Construction Summary MW-148

Location: FT-1 Loc #15 Alluvial   Elevation: Ground Level ____________

Personnel: G. D. Gregory   Top of Casing ____________

DRILLING SUMMARY:

Total Depth 10'

Borehole Diameter 8"

Driller Don Clawson
Environmental West

Rig Mobile Drill B61

Bit(s) 8" Auger

Drilling Fluid N/A

Surface Casing N/A

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

+2.5 - 5	C	
5 - 10	S	

Casing: C1 Schedule 40, 2" PVC
C2
C3
C4

Screen: S1 [illegible]
S2
S3
S4

Centralizers N/A

Filter Material CSI 10/20 sand

Cement Concrete

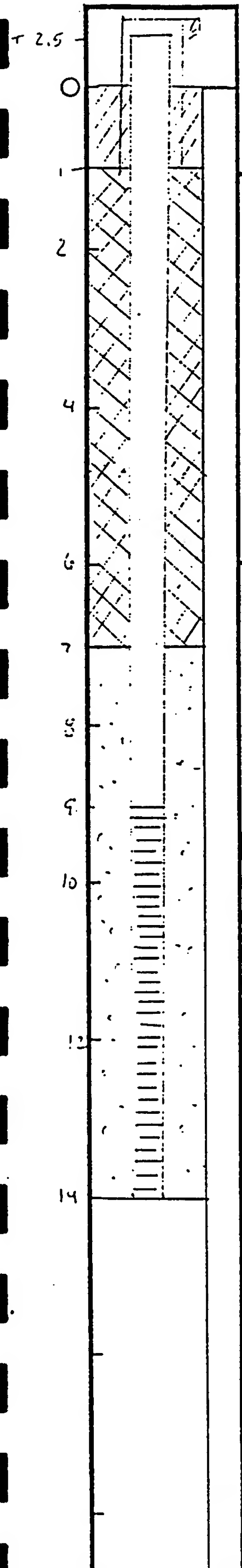
Other [illegible] Bentonite hole plug

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	[illegible]	[illegible]	[illegible]	[illegible]
Geophys. Logging:				
Casing:	[illegible]	[illegible]	[illegible]	[illegible]
Filter Placement	11-12-91	[illegible]	11-12-91	[illegible]
Cementing:				
Bentonite Seal:	[illegible]	[illegible]	11-12-91	[illegible]
Other:				

Comments:
- [illegible]
- Installed above surface [illegible] well monument

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel



Well Construction Summary MW-149

Location: FT-1 Lot #14 Silhwick

Personnel: G. DiGregorio

Elevation: Ground Level ______

Top of Casing ______

DRILLING SUMMARY:

Total Depth 14'

Borehole Diameter 8"

Driller Dixon Clawson
Environmental West

Rig Mobile Drill B61

Bit(s) 8" Auger

Drilling Fluid N/A

Surface Casing N/A

WELL DESIGN:

Basis:
Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

+2.5	4	C
4	14	S

Casing: C1 2" schedule 40 PVC
C2
C3
C4

Screen: S1 2" schedule 40 PVC 0.010 slot
S2
S3
S4

Centralizers N/A

Filter Material CSI 10-20 sand

Cement bentonite

Other hydration of bentonite with bentonite hole plug

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
Geophys. Logging:				
Casing:	11-12-91	0922	11-12-91	0922
Filter Placement	11-12-91	0925	11-12-91	0940
Cementing:				
Bentonite Seal	11-12-91	0940	11-12-91	0952
Other:				

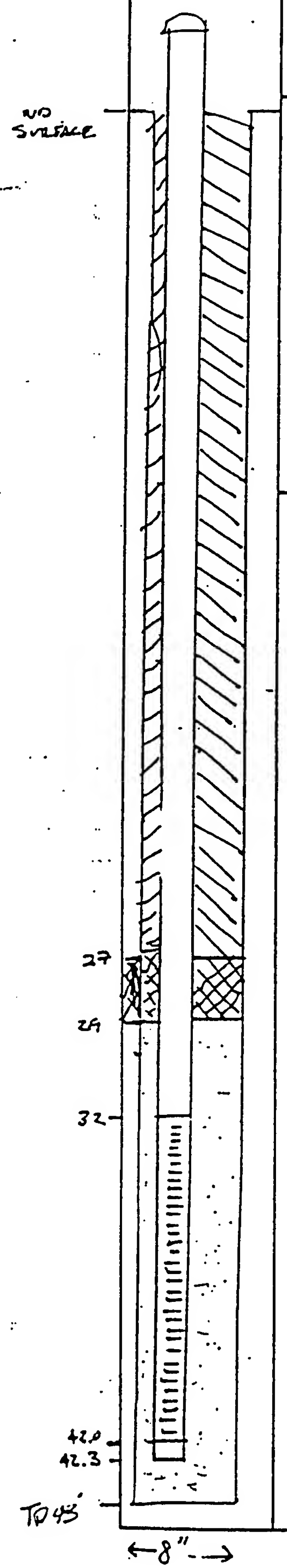
Comments:
Installed above surface locking well monument
- hydrated bentonite w/ 5 gal of potable water

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel

Well Construction Summary

Location: FT-1 Loc 12 MW150 Elevation: Ground Level ______

Personnel: CHUCK HOUCK (SAIC) PONDEROSA DRILLING Top of Casing ______



DRILLING SUMMARY:

Total Depth 43' bgs

Borehole Diameter 8"

Driller PONDEROSA - LOUIE HARPER - RIDER

Rig CP 780

Bit(s) 8" TRI-CONE 8" ROCK HAMMER

Drilling Fluid AIR/WATER

Surface Casing 8" steel

WELL DESIGN:

Basis: Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

42.3 - 42.0	C	
42 - 32	S	
32 - +2.5	C	

Casing: C1 42.3 - 42 PVC Sch 40 end plug
C2 32 - 2.5 AGS PVC sch 40 (4")
C3
C4

Screen: S1 42-32 PVC Sch 40 .020 (4")
S2
S3
S4

Centralizers Ø

Filter Material 10-20 C

Cement PORTLAND TYPE II 10 bags 25'-0'

Other Bentonite pellets 29'-27' bgs

CONSTRUCTION TIME LOG:

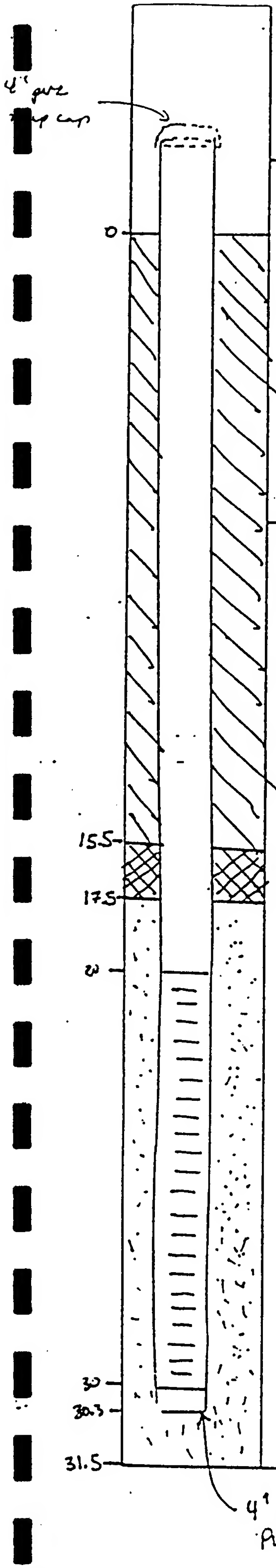
Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: AIR ROTARY 8"	9/18/91	1400	9/18/91	1650
Geophys. Logging:				
Casing:	9/20/91	0700	9/20/91	0720
Filter Placement:	9/20/91	0720	9/20/91	0740
Cementing:	9/20/91	1400	9/20/91	1430
Development:				
Other: removal of casing (steel)	9/20/91	0740	9/20/91	1400

Comments: drill rig down 9/19/91 0700-1200 (repairs) Standby down 9/19/91 1200-1430 waiting for delivery of well material standby 1430-1700 waiting for decisions on type of well casing/screen 9/20/91 - steel driving casing stuck 0740 - 1430 - finally dislodged

4" end plug (threaded)

Key:

Bentonite Sand
Cement/Grout Silt
Sand Pack Clay
Drill Cuttings Screen
Gravel



Well Construction Summary

Location: ET-1 Loc #2 MW152 151
Elevation: Ground Level ______
Personnel: Chuck Houck (SAIC) Louis + Roger (Ponderosa Drilling)
Top of Casing ______

DRILLING SUMMARY:

Total Depth 31.5
Borehole Diameter 8"
Driller Ponderosa
Rig CP 780
Bit(s) 8" tricone
Drilling Fluid Air/Water
Surface Casing None

WELL DESIGN:

Basis: Geologic Log | Geophysical Log

Casing String(s): C=Casing S=Screen

30.3 - 30	C	
30 - 20	S	
20 - +2.5	C	

Casing: C1 4" PVC threaded endplug
C2 4" sch 40
C3
C4

Screen: S1 4" threaded PVC sch 40-020
S2
S3
S4

Centralizers None

Filter Material 10-20 silica sand

Cement Portland Type II

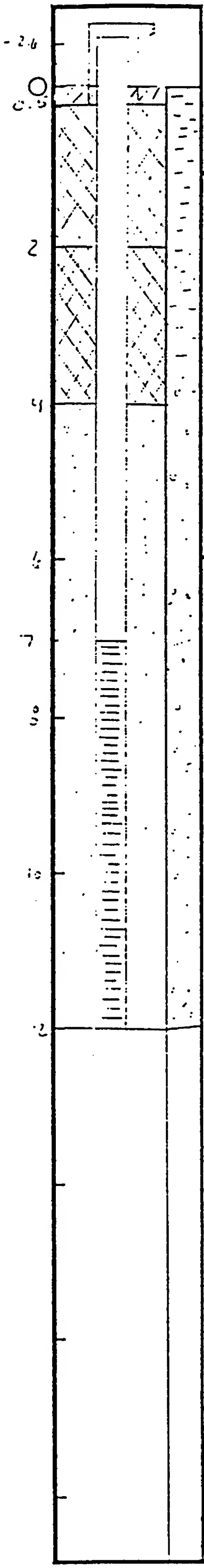
Other ~~Bell~~ 3/4" Bentonite Pellets

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: Air Rotary	9/21/91	0900	9/21/91	1100
Geophys. Logging:				
Casing:	9/21/91	1100	9/21/91	1110
Filter Placement:	9/21/91	1110	9/21/91	1115
Cementing:	9/21/91	1120	9/21/91	1130
Development:				
Other:				

Comments: started pulling steel casing 1140 very slow pulling. finished pulling casing 1400. Driller did not have security box - will set security box when available

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel



Well Construction Summary MW-152

Location: FT-1 Loc #12 Alluvial

Elevation: Ground Level

Personnel: G. D. Gregorio

Top of Casing

DRILLING SUMMARY:

Total Depth 12'

Borehole Diameter 8"

Driller Don Clausen
Environmental West

Rig Mobile Drill B61

Bit(s) 8" Augers

Drilling Fluid N/A

Surface Casing N/A

WELL DESIGN:

Basis:
Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

+2.6 - 7	C				
7 - 12	S				

Casing: C1 2" schedule 40 PVC
C2
C3
C4

Screen: S1 2" schedule 40 PVC w/ 0.020 slot
S2
S3
S4

Centralizers N/A

Filter Material CSI sand 10/20

Cement cement grout

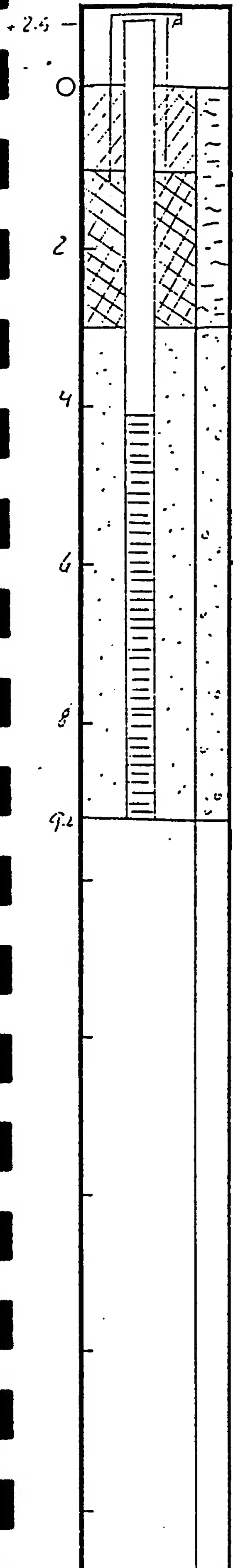
Other Volclay bentonite pellets 3/8"
Pentonite hole plug

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	[illegible]	1145	[illegible]	1220
Geophys. Logging:				
Casing:	[illegible]	1225	[illegible]	[illegible]
Filter Placement	11-12-91	1230	11-12-91	1240
Cementing:				
Bentonite Seal:	11-12-91	1245	11-12-91	1252
Other:				

Comments:
- Above surface locking well monument
- hydrated bentonite w/ 5 gal of potable water

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel



Well Construction Summary MW-153

Location: FT-1 Lot #17 Alluvial Elevation: Ground Level ____________

Personnel: G. D. Grigg Top of Casing ____________

DRILLING SUMMARY:

Total Depth 9.2'

Borehole Diameter 8"

Driller Dan Classen, Environmental West

Rig Mobile Drill B61

Bit(s) 8" Augers

Drilling Fluid NA

Surface Casing NA

WELL DESIGN:

Basis:
Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

From	To	Type
+2.5	4	C
4	9.2	S

Casing: C1 2" schedule 40 PVC
C2
C3
C4

Screen: S1 2" schedule 40 PVC w/.020" slots
S2
S3
S4

Centralizers NA

Filter Material CSI 10/20 Sand

Cement Concrete

Other Volclay 3/8" bentonite pellets, bentonite hole plug

CONSTRUCTION TIME LOG:

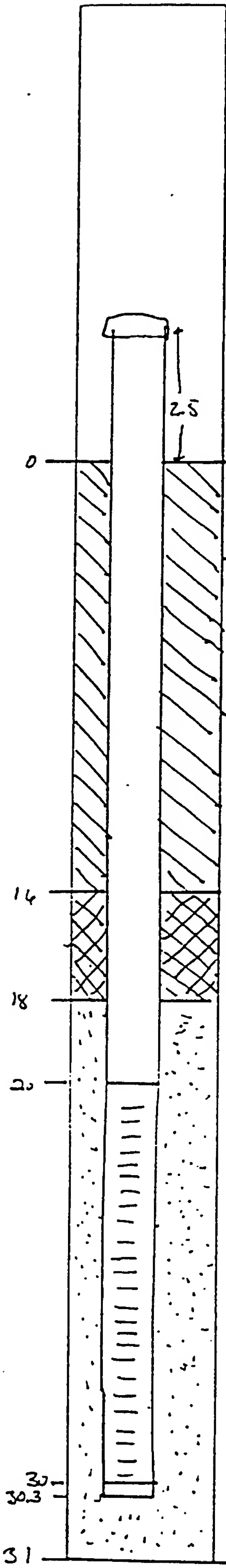
Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	11-13-91	0726	11-13-91	[illegible]
Geophys. Logging:				
Casing:	11-13-91	[illegible]	11-13-91	[illegible]
Filter Placement	11-13-91	0813	11-13-91	[illegible]
Cementing:				
Bentonite Seal	11-13-91	[illegible]	11-13-91	[illegible]
Other:				

Comments:

Installed above ground locking well monument
hydrated bentonite w/ 5 gal potable water

Key:

Bentonite Sand
Cement/Grout Silt
Sand Pack Clay
Drill Cuttings Screen
Gravel



Well Construction Summary

MW154

Location: FT-1 Loc 11 ______ Elevation: Ground Level ______

Personnel: SAIC / PONDEROSA ______ Top of Casing ______

DRILLING SUMMARY:

Total Depth 31'

Borehole Diameter 8"

Driller Louie Hanner - Ponderosa
Rock Valley - helper

Rig CP 780

Bit(s) 8" tricone - 8" hammer bit

Drilling Fluid AIR / WATER

Surface Casing NONE

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: AIR ROT	9/21/91	1600	9/22/91	0930
Geophys. Logging:				
Casing:	9/22/91	0940	9/22/91	0950
Filter Placement:	9/22/91	1000	9/22/91	1015
Cementing:	9/22/91	1020	9/22/91	1030
Development:				
Other:				

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

From	To	Type
30.3	30	C
30	20	S
20	+2.5	C

Casing: C1 4"x4" PVC end cap
C2 4" sch 40 PVC
C3
C4

Screen: S1 4" Sch 40 PVC w/ .020 slot
S2
S3
S4

Centralizers NONE

Filter Material 10/20 Silica Sand
31-18

Cement 18-2 Portland Type II
5 bag + 5% bentonite

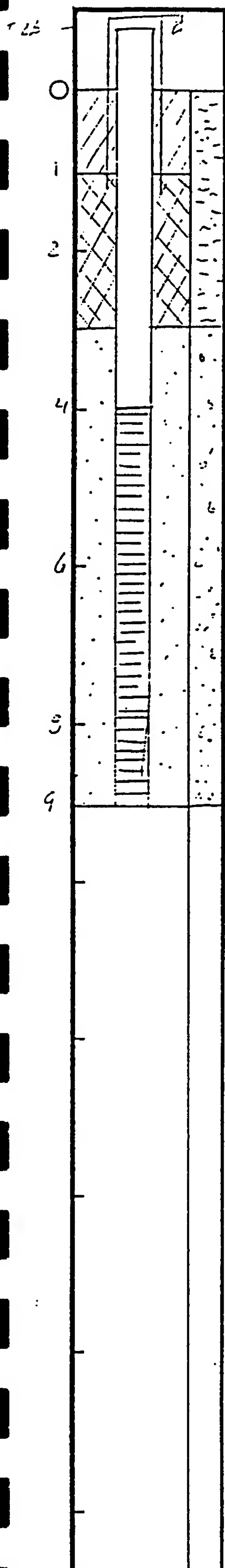
Other 3/8" Volclay bentonite pellets - 18-16

Comments:

Did not use cutting shoe on hammer casing - came out relatively easy

Key:

Bentonite
Cement/Grout
Sand Pack
Drill Cuttings
Gravel
Sand
Silt
Clay
Screen



Well Construction Summary MW-155

Location: FT-1 [illegible] Alluvial
Elevation: Ground Level ______
Personnel: G. D. Gregory
Top of Casing ______

DRILLING SUMMARY:

Total Depth 9'
Borehole Diameter 8"

Driller D. Claassen
Environmental [illegible]
Rig Mobile Drill B61
Bit(s) 8" Augers

Drilling Fluid N/A

Surface Casing N/A

WELL DESIGN:

Basis:
Geologic Log · Geophysical Log
Casing String(s): C=Casing S=Screen

+2.5 - 4	C	
4 - 9	S	

Casing: C1 2" Schedule 40 PVC
C2
C3
C4

Screen: S1 2" Schedule 40 PVC 0.010 slot
S2
S3
S4

Centralizers N/A

Filter Material CSI 10/20 Sand

Cement Grout

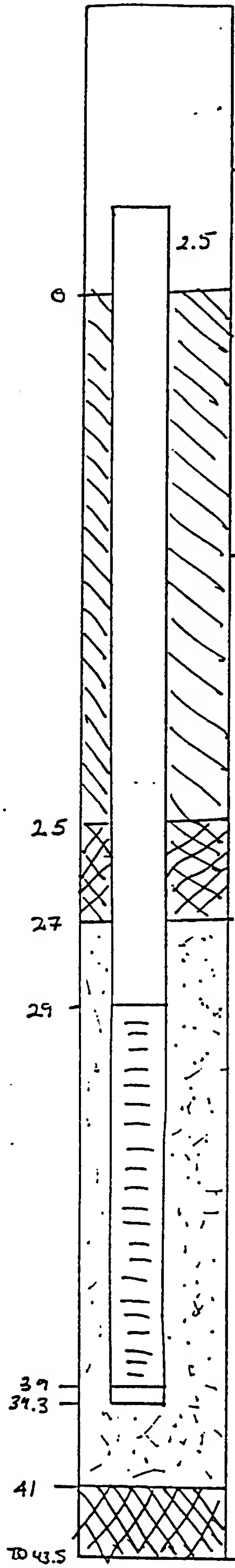
Other [illegible] 3/0' bentonite pellets

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	11-12-91	1340	11-12-91	[illegible]
Geophys. Logging:				
Casing:	11-12-91	1410	11-12-91	1410
Filter Placement	11-12-91	1417	11-12-91	1427
Cementing:	11-12-91		11-12-91	
Bentonite Seal	11-12-91	1028	11-12-91	1032
Other:				

Comments:
- Installed above ground well monument
- [illegible]

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel



Well Construction Summary

Location: FT-1 loc. 1 MW156
Personnel: Chuck Houck (SAIC)

Elevation: Ground Level ______
Top of Casing ______

DRILLING SUMMARY:

Total Depth 43.5'
Borehole Diameter 8"
Driller Louis Homer - PONDEROSA
Rig CP 780
Bit(s) 8" tricone + 8" hammer bit
Drilling Fluid AIR/WATER
Surface Casing NONE

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: AIR ROT.	9/22/91	1400	9/22/91	1735
Geophys. Logging:				
Casing:	9/23/91	0900	9/23/91	0920
Filter Placement:	9/23/91	0920	9/23/91	0925
Cementing:	9/23/91	0925	9/23/91	0950
Development:				
Other:				

WELL DESIGN:

Basis:
Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

~~43~~ -		
39.3 - 39	C	
39 - 29	S	
29 - +2.5 bls	C	

Casing: C1 4"x4" Threaded PVC end plug
C2 4" PVC SCH40
C3
C4

Screen: S1 4" Sch40 PVC 0020 slot
S2
S3
S4

Centralizers None

Filter Material 10/20 Silica Sand
41 - 27

Cement ~~5~~ 5 bag + 5%

Other 3/8" VoClay pellets
43.5 - 41 / 27 - 25

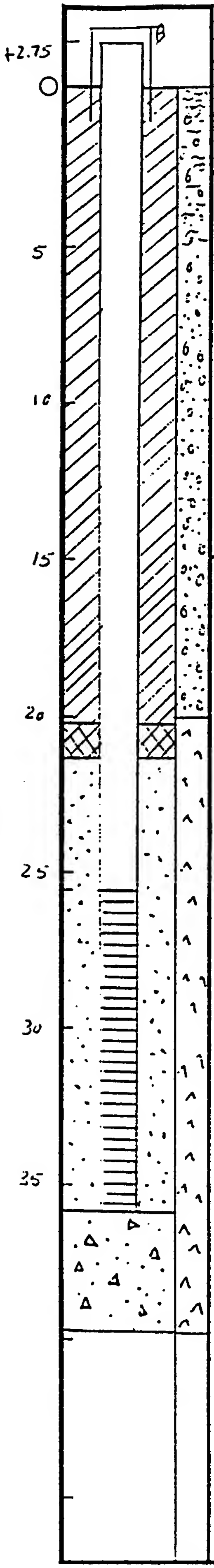
Comments:

NUS wanted to drill twenty feet into bedrock to see if any fractured or weathered zones existed in upper 20 feet of bedrock - more water - backfilled 2.5 feet of boring and set similar to previous FT-1 shallow bedrock well.

Key:

Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel

MW-157



Well Construction Summary

Location: FT-1 Shallow #2

Elevation: Ground Level ____

Personnel: A. Cavazos, C. Hauck, G. DiGregorio

Top of Casing ____

DRILLING SUMMARY:

Total Depth 39.5'

Borehole Diameter 8"

Driller Louie Hanner / Ponderosa

Rig CP 7000

Bit(s) 8" tricone roller and 8" percussion hammer

Drilling Fluid water

Surface Casing N/A

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

+2.75 - 26.4	C1
26.4 - 36.5	S

Casing: C1 4" Schedule 40 PVC
C2
C3
C4

Screen: S1 4" Schedule 40 PVC w/ 0.02 slot
S2
S3
S4

Centralizers N/A

Filter Material CSS 10-20

Cement Lafarge Type I-II

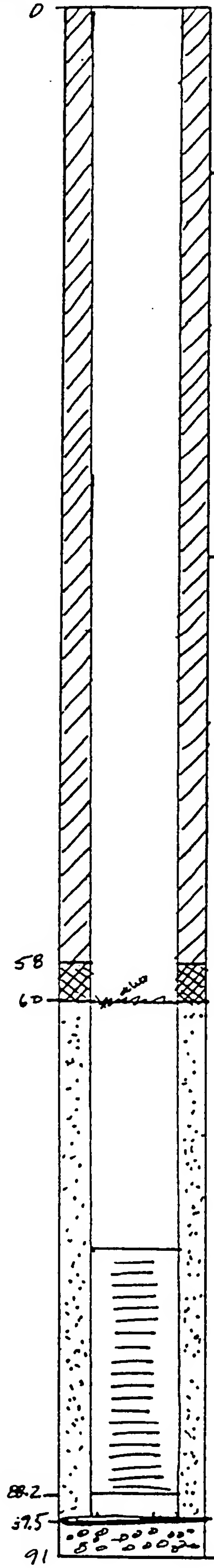
Other Aqua gel gold seal bentonite and Volclay bentonite pellets

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	10-7-91	0815	10-14-91	1008
Geophys. Logging:				
Casing:	10-14-91	1112	10-14-91	1123
Filter Placement		1128		1138
Cementing:		1233 [illegible]		1405 ~~1153~~
Bentonite Seal		1139		1153
Other:				

Comments:
Well completed with steel locking monument in place.

Key:
Bentonite
Cement/Grout
Sand Pack
Drill Cuttings
Gravel
Sand
Silt
Clay
Screen
Basalt



Well Construction Summary

MW158

Location: FT-1 Mid Pump

Elevation: Ground Level ____________

Personnel: A. Cuvazos, SAIC

Top of Casing ____________

DRILLING SUMMARY:

Total Depth 91' (caved in overnight) 89.5'

Borehole Diameter 8"

Driller Louie Hayner, Ponderosa

Rig CP 7000

Bit(s) 8" tricone roller, 8" hammer bit

Drilling Fluid air, water

Surface Casing ____________

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling: Air rotary	10/3/91	0940	10/4/91	1405
Geophys. Logging:				
Casing: Sch 40 6" PVC and Sch 40 6" 020 slot screen, 6"x9" PVC end plug	10/5/91		10/5/91	1130
Filter Placement:	"	1130	"	1330
Cementing:	"	1400	"	1510
Development:				
Other: Install security box	"	1510	"	1520
Bentonite plug	"	1330	"	1400

WELL DESIGN:

Basis:

Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

89.5 - 88.2 C1

88.2' - 78.2' S

78.2' - 2.5' AGL C2

Casing: C1 6" x 9" PVC + threaded end plug

C2 6" Sch 40 PVC

C3

C4

Screen: S1 6" Sch 40 PVC 020 slot

S2

S3

S4

Centralizers none

Filter Material 10/20 Silica sand 89.5' - 60'

Cement Portland Type I-II 58' - 0

Other Volclay 3/8" bentonite pellets 60'-58'

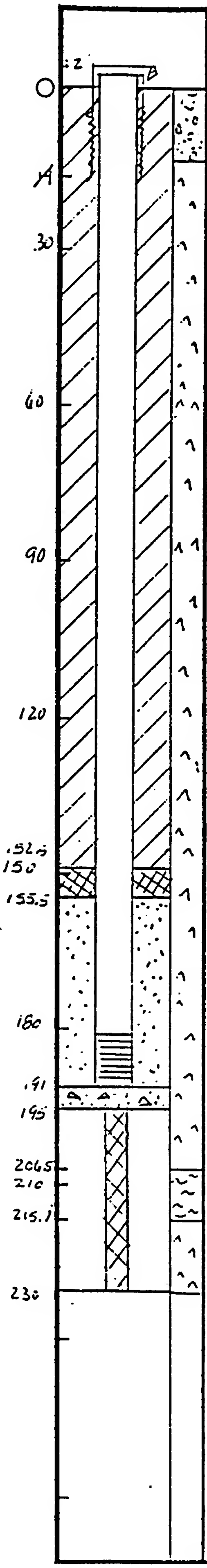
Comments:

Cave in occurred overnight (10/4/91). On 10/5/91 TD was 89.5'. When installing filter, ~~[illegible]~~ at ~ 70' depth took add'l filter mat'l to fill.

Key:

Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel

MW-159



Well Construction Summary

Location: FT-1 Core hole MW159 Elevation: Ground Level ______

Personnel: G. DiGregorio Top of Casing ______

DRILLING SUMMARY:

Total Depth 195'

Borehole Diameter 10"

Driller Louie Hanner / Ponderosa

Rig CP 7000

Bit(s) 10" Tricone roller and percussion hammer

Drilling Fluid water

Surface Casing NA

WELL DESIGN:

Basis:

Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

+2.0 - 181	C1	
181 - 191	S1	
~~0 - 14'~~	~~C2~~ GD	

Casing: C1 6" Schedule 40 PVC

C2 ~~12" steel surface casing~~ GD

C3

C4

Screen: S1 6" Schedule 40 w/ 0.02 slots

S2

S3

S4

Centralizers NA

Filter Material CSS 10-20

Cement Lafarge Type I-II

Other Aqua gel gold seal bentonite Volclay bentonite pellets

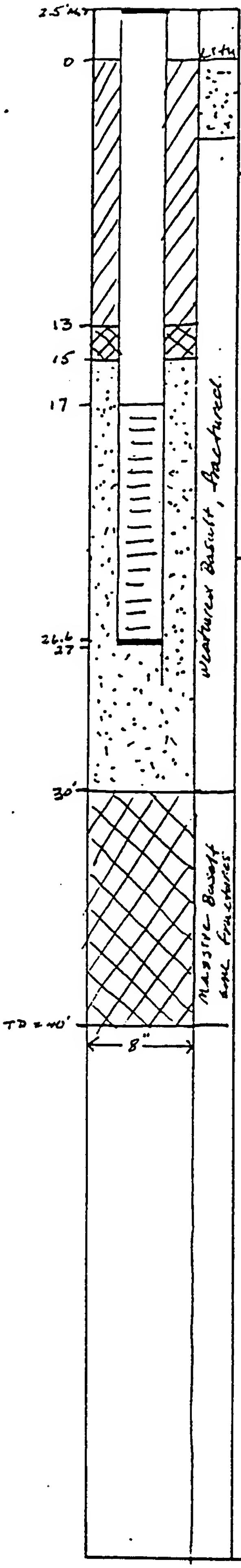
CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	102091	1331	102291	1201
Geophys. Logging:				
Casing:	102291	1425	102291	1513
Filter Placement	102291	1515	102291	1534
Cementing:	10239	0901	102391	0950
Bentonite Seal:	102291	1535	102291	1555
Other: Developed	11-2-91			

Comments: Well completed with locking steel monument in place

Key:

Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel
Basalt



Well Construction Summary

MW-160

Location: FT-1 Loc ~~5?~~ 4/6

Elevation: Ground Level ______

Personnel: Anne Cavazos, SAIC

Top of Casing ______

DRILLING SUMMARY:

Total Depth 40'

Borehole Diameter 8"

Driller Alvin Carris, Ponderosa

Rig CP 650

Bit(s) 8" tricone roller, 8" hammer bit

Drilling Fluid air, water

Surface Casing ______

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:	10/16/91	1430	10/17/91	1300
Geophys. Logging:				
Casing: Endcap, screen, casing	10/17/91	1420	10/17/91	1435
Filter Placement:	10/17/91	1415	10/17/91	14~~45~~
Cementing:	10/17/91	1450	10/17/91	1625
Development:				
Other: 3/8" Volclay bentonite pellets:	10/17/91	1445	10/17/91	1450
Bentonite Hole plug:	10/17/91	1330	10/17/91	1415

WELL DESIGN:

Basis:
Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

From	To	
27	26.6	C1
26.6	17	S
17	2.5 AGS	C2

Casing: C1 PVC Endplug 2" + 5" (Monoflex)
C2 Sch 40 2" PVC (monoflex)
C3 ______
C4 ______

Screen: S1 Sch 40 2" PVC w/ .020 slots (monoflex)
S2 ______
S3 ______
S4 ______

Centralizers none

Filter Material 10/20 Colorado Silica sand (30'-15') 7 bags

Cement Lafarge Portland cement Type I-II w/ 5% Aquagel Gold Seal Bentonite

~~Other~~ (13'-0') 10 bgs + 1/2

Other: 3/8 Bentonite Holeplug (40-30', 4 bags) 3/8" Volclay bentonite pellets, (15'-13', 1 bucket)

Comments:

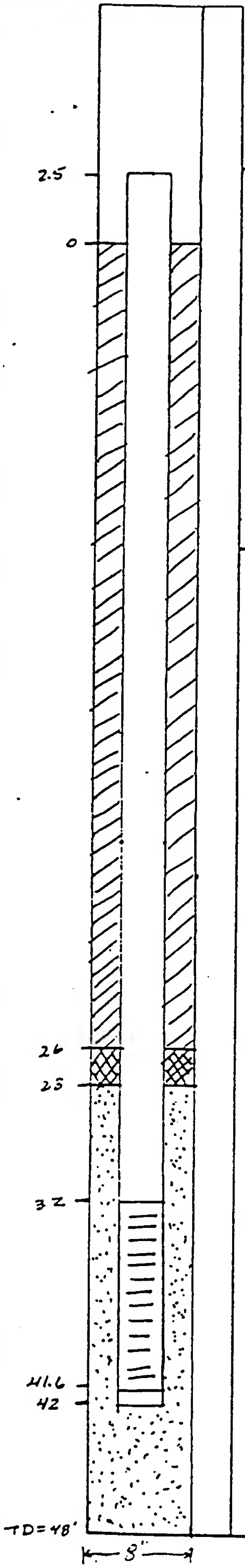
Key:

- Bentonite
- Sand
- Cement/Grout
- Silt
- Sand Pack
- Clay
- Drill Cuttings
- Screen
- Gravel

MW1-

Well Construction Summary

MW 161



Location: FT-1 Loc ~~#3~~ 7/9

Personnel: Greg DiGregorio (SAIC)(geologist) / A. Cavazos (SAIC)(set well)

Elevation: Ground Level ______

Top of Casing ______

DRILLING SUMMARY:

Total Depth 48" BGS

Borehole Diameter 8"

Driller Alvin Carns, Ponderosa

Rig CP 650

Bit(s) 8" tricone roller, 8" hammer bit

Drilling Fluid air, water

Surface Casing ______

WELL DESIGN:

Basis:

Geologic Log   Geophysical Log

Casing String(s): C=Casing S=Screen

42.0 - 41.8	C1	
41.8 - 32	S1	
32 - 2.5' AGS	C2	

Casing: C1 2" dia endcap - Johnson

C2 2" Sch 40 PVC - "

C3

C4

Screen: S1 2" Sch 40 PVC .020 slots, Johnson

S2

S3

S4

Centralizers ______

Filter Material 10/20 Colorado Silica Sand (48'-28')

Cement Portland Type I-II (Lafarge) w/5% Aquagel Gold Seal Bentonite clay (26'-0')

Other Volclay 3/8" bentonite pellets (28-26')

CONSTRUCTION TIME LOG:

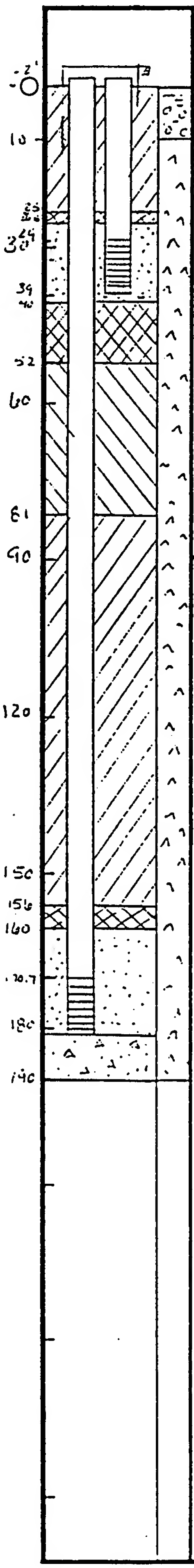
Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:			10/16/91	0820
Geophys. Logging:				
Casing: ~~Stick~~ Endcap, screen, casing	10/16/91	0900	10/16/91	0920
Filter Placement:	10/16/91	0830	10/16/91	0935
Cementing:	10/16/91	0945	10/16/91	1200
Development:				
Other: 3/8" bentonite pellets	10/16/91	0935	10/16/91	0945

Comments:

Key:

- Bentonite
- Sand
- Cement/Grout
- Silt
- Sand Pack
- Clay
- Drill Cuttings
- Screen
- Gravel

MW-162 / MW-163
MW-162 Shallow
MW-163 - Deep



Well Construction Summary

Location: FT-1 Nest #2
Elevation: Ground Level ______
Personnel: G. D. Gregorio
Top of Casing ______

DRILLING SUMMARY:

Total Depth 190'
Borehole Diameter 10"

Driller Louie Hauser / Ponderosa

Rig CP 7000
Bit(s) 10" Tricone roller and percussion hammer
Drilling Fluid water

Surface Casing 12" Steel

WELL DESIGN:

Basis:
Geologic Log Geophysical Log

Casing String(s): C=Casing S=Screen

+2 – 170.7	C1	170.7 – 181	S1
+2 – 29	C2	29 – 39	S2
0 – 14'	C3	–	
–		–	
–		–	
–		–	
–		–	
–		–	

Casing: C1 2" Schedule 40 PVC
C2 2" Schedule 40 PVC
C3 12" Steel
C4

Screen: S1 2" Schedule 40 w/ 0.02 slot
S2 2" Schedule 40 w/ 0.02 slot
S3
S4

Centralizers N/A

Filter Material CSS 10-20

Cement Lafarge Type I - II

Other Aqua gel Gold seal bentonite Volclay bentonite pellets

CONSTRUCTION TIME LOG:

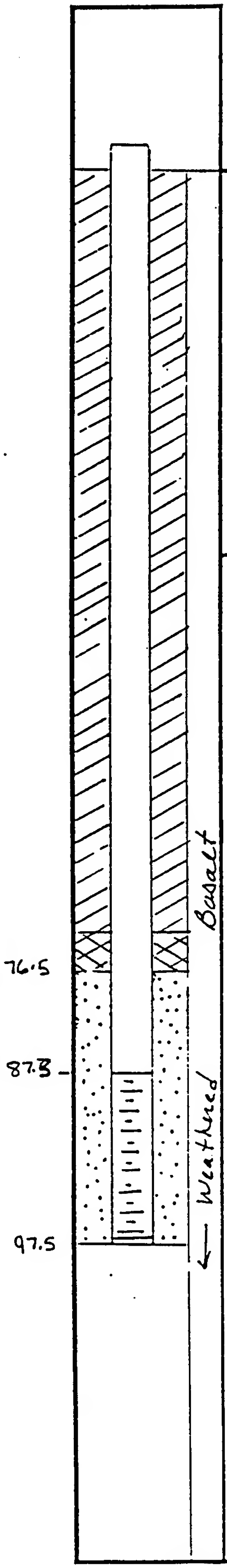
Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
	101491	1402	101491	[illegible]
Geophys. Logging:				
Casing: C1	101991	0751	101991	[illegible]
C2	102291	1009	102291	1110
C3	101691	0842	101691	[illegible]
C1 Filter Placement	101991	0815	101991	[illegible]
C1 Cementing:	101991	0934	102091	0821
C1 Bentonite Seal:	101991	[illegible]	101991	[illegible]
Other:				
C2 Filter Placement	102291	1110	102291	11:14
C2 Cementing	102391	1330	102391	1334
C2 Bentonite Seal	102291	11:21	102291	11:22
Bentonite plug	102191	1032	102191	1104

Comments:

The well was completed with a locking steel monument in place.

Key:

Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel
Basalt



Well Construction Summary

Location: SW1 Lot 5 MW86 Elevation: Ground Level ______

Personnel: N. Gonister Top of Casing ______

DRILLING SUMMARY:

Total Depth ______

Borehole Diameter 8"

Driller Ponderosa

Rig CP 7000

Bit(s) 8" hammer

Drilling Fluid Water

Surface Casing ______

WELL DESIGN:

Basis:
Geologic Log ___ Geophysical Log ___

Casing String(s): C=Casing S=Screen

97.5 - 97.3	C1	
97.3 - 87.3	S1	
87.3 - +2.5	C2	

Casing: C1 2" PVC end Cap
C2 2" Sch 40 Blank
C3
C4

Screen: S1 2" PVC .020 Slot
S2
S3
S4

Centralizers ______

Filter Material 10/20 Colorado Silica Sand

Cement Portland Type II 5% bentonite

Other 3/8" Volclay bentonite pellets

CONSTRUCTION TIME LOG:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling:				
8" Ream/Drill	04Dec91	1335		
			05Dec91	0845
Geophys. Logging:				
Casing:				
2" PVC	05Dec91	0925		0935
Filter Placement	05Dec91	0935		0940
Cementing:	05Dec91	0943		1035
Bentonite Seal:	05Dec91	0940		0943
Other:				

Comments:
Extended Sand Pack

Key:
Bentonite
Sand
Cement/Grout
Silt
Sand Pack
Clay
Drill Cuttings
Screen
Gravel

APPENDIX G2:

MONITORING WELL COMPLETION INFORMATION
SELECTED WELLS MW-1 THROUGH MW-134

Appendix G-2
Table 1
Monitoring Well Screen Intervals and
Corresponding Hydrogeologic Units (1)
Fairchild AFB, Washington

Well No. (a)	Site	Total Depth (ft. BGL)(b)	Bottom of Screen Depth (ft. BGL)	Screened Interval (ft. BGL)	Hydrogeologic Unit (c)
MW-01*	FT-1	15.0	10.0	4.50-10.00	Qal
MW-02*	FT-1	14.0	11.8	6.30-11.80	Qal
MW-03*	FT-1	11.0	9.0	3.50- 9.00	Qal
MW-04*	FT-1	15.0	12.85	7.35-12.85	Qal
MW-05*	WW-1	17.5	15.0	9.50-15.00	Qal
MW-06*	WW-1	17.5	16.75	5.00-16.75	Qal
MW-07*	WW-1	13.5	12.5	7.50-12.50	Qal
MW-08*	WW-1	13.5	12.5	7.00-12.50	Qal
MW-09*	WW-1	11.0	10.0	4.50-10.00	Qal
MW-10*	WW-1	18.5	17.0	5.75-17.00	Qal
MW-11*	WW-1	20.0	16.5	5.65-16.50	Qal
MW-12*	WW-1	15.0	13.0	7.50-13.00	Qal
MW-13*	WW-1	15.5	13.55	8.05-15.55	Qal
MW-14	PS-1	16.5	8.0	2.20- 8.00	Qal
MW-15	PS-1	8.5	8.2	2.63- 8.20	Qal
MW-16	PS-1	13.5	11.5	5.75-11.50	Qal
MW-17*	SW-8	23.5	21.86	5.56-21.86	Qal
MW-18*	SW-8	19.0	18.5	7.54-18.50	Qal
MW-19*	SW-8	33.5	32.0	1.00-32.00	Qal
MW-20*	SW-8	42.0	41.3	25.30-41.30	Qal
MW-21*	SW-8	50.0	49.25	33.25-49.25	Qal
MW-22*	SW-8	15.5	14.75	9.25-14.75	Qal
MW-23*	SW-8	14.5	13.75	8.15-13.75	Qal
MW-24*	SW-8	16.5	16.3	10.00-16.30	Qal
MW-25*	IS-1	8.5	7.5	2.00- 7.50	Qal
MW-26*	SW-1	8.5	7.76	2.26- 7.76	Qal
MW-27*	SW-1	7.5	6.72	1.22- 6.72	Qal
MW-28*	SW-1	18.0	17.65	12.15-17.65	Qal
MW-29*	SW-1	8.5	8.0	2.50- 8.00	Qal
MW-30*	PS-8	28.5	13.0	7.50-13.00	Qal
MW-31*	PS-8	13.5	12.6	7.10-12.60	Qal
MW-32*	PS-8	12.0	11.18	5.68-11.18	Qal
MW-33	PS-6	13.5	10.5	5.00-10.50	Qal
MW-34	PS-6	17.5	17.5	11.50-17.50	Qal
MW-35	PS-6	18.0	12.93	7.43-12.93	Qal
MW-36	BW-1	26.5	23.25	18.00-23.25	Qal
MW-37	IS-4	9.0	8.7	3.45-8.70	Qal
MW-38	BW-1	26.6	20.0	10.00-20.00	A (top)
MW-39	BW-1	46.0	43.15	32.90-43.15	A (top)
MW-40	PS-5	17.5	17.5	7.50-17.50	Qal
MW-41	PS-5	12.8	12.8	7.80-12.80	Qal
MW-42	PS-5	17.5	17.5	7.50-17.50	Qal
MW-43	PS-9	38.5	15.0	10.00-15.00	Qal
MW-44	PS-9	11.5	10.0	5.00-10.00	Qal
MW-45	PS-9	11.5	10.0	5.00-10.00	Qal
MW-46	PS-5	57.0	57.0	47.30-57.30	A (top-mid)
MW-47	BW-1	22.5	20.5	10.50-20.50	Qal
MW-48*	WW-1	15.0	15.0	10.00-15.00	Qal
MW-49*	WW-1	13.0	13.0	8.00-13.00	Qal
MW-50*	FT-1	20.0	16.0	6.00-16.00	Qal
MW-51*	FT-1	10.0	10.0	5.00.10.00	Qal
MW-52*	FT-1	15.6	15.6	5.60-15.60	Qal
MW-53*	FT-1	21.6	21.5	11.50-21.50	Qal
MW-54*	WW-1	13.0	13.0	8.00-13.00	Qal
MW-55*	PS-2	16.6	16.6	6.35-16.60	Qal
MW-56*	PS-2	13.0	13.0	7.75-13.00	Qal
MW-57	BW-1	6.5	6.5	1.25-6.50	Qal
MW-58	BW-1	10.0	10.0	5.00-10.00	Qal
MW-59*	WW-1	73.5	70.0	59.50-70.00	A (mid)
MW-60*	WW-1	69.0	68.0	57.75-68.00	A (mid)

Appendix G-2
Table 1
Monitoring Well Screen Intervals and Corresponding Hydrogeologic Units (1)
Fairchild AFB, Washington
(continued)

Well No. (a)	Site	Total Depth (ft. BGL)(b)	Bottom of Screen Depth (ft. BGL)	Screened Interval (ft. BGL)	Hydrogeologic Unit (c)
MW-61•	FT-1	72.0	70.0	59.50-70.00	A (mid)
MW-62	BW-1	43.0	42.0	31.54-42.00	A (top)
MW-63•	SW-8	105.0	104.0	93.50-104.00	A (top-mid)
MW-64	BW-1	14.5	14.5	9.50-14.50	Qal
MW-65	BW-1	24.5	24.5	14.50-24.50	Qal
MW-66•	PS-8	37.5	18.0	8.00-18.00	Qal
MW-67•	PS-8	20.5	20.0	10.00-20.00	Qal
MW-68•	PS-8	18.0	17.0	7.00-17.00	Qal
MW-69•	SW-8	45.0	45.0	35.00-45.00	A (top)
MW-70•	SW-8	27.7	27.7	17.70-27.70	A (top)
MW-71	PS-7	21.0	20.5	10.50-20.50	A (top)
MW-72	PS-7	32.0	32.0	22.00-32.00	A (top)
MW-73	PS-7	18.0	17.5	7.50-17.50	A (top)
MW-74•	SW-8	185.66	184.66	173.10-184.66	B (top)
MW-75•	SW-8	87.5	87.5	76.00-87.50	A (top)
MW-76•	SW-8	66.3	66.3	54.80-66.30	A (top)
MW-77•	SW-8	96.0	95.0	83.50-95.00	A (mid)
MW-78•	SW-8	101.3	99.0	87.50-99.00	A (top-mid)
MW-79•	SW-8	386.0	385.5	374.00-385.50	Interbed B
MW-80•	SW-8	120.5	120.5	109.00-120.50	A (top)
MW-81•	SW-8	83.4	82.2	70.70-82.20	A (top-mid)
MW-82•	SW-8	82.5	81.5	70.00-81.50	A (top)
MW-83•	SW-8	148.7	144.5	133.00-144.50	A (mid)
MW-84•	SW-8	128.1	1126.9	115.40-126.90	A (top-mid)
MW-85•	SW-8	108.6	107.6	96.10-107.60	A (top-mid)
MW-86•	SW-1	--	--	--	--
MW-87•	SW-1	20.07	17.0	6.77-17.00	A (top)
MW-88•	SW-1	15.7	15.7	5.47-15.70	A (top)
MW-89•	SW-1	26.4	26.4	16.17-26.40	A (top)
MW-90•	SW-1	45.2	44.0	33.77-44.00	A (top-mid)
MW-91•	IS-1	17.2	17.2	6.97-17.20	A (top)
MW-92•	IS-1	40.0	40.0	29.70-40.00	A (top-mid)
MW-93•	IS-1	25.16	25.16	14.93-25.16	A (top)
MW-94•	SW-8	153.8	150.11	139.78-150.11	A (base)
MW-95•	SW-8	149.3	147.0	136.97-147.00	A (base)
MW-96•	SW-8	145.54	144.0	133.67-144.00	A (base)
MW-97•	SW-8	148.88	148.88	138.55-148.88	A (base)
MW-98•	FT-1	203.46	203.46	193.13-203.46	A (base)
MW-99•	WW-1	75.76	75.76	65.43-75.76	A (mid)
MW-100•	FT-1	53.43	53.43	43.10-53.43	A (mid)
MW-101•	SW-8	201.64	201.64	191.39-201.64	B (top)
MW-102•	WW-1	16.64	16.64	6.39-16.64	Qal
MW-103•	WW-1	16.13	14.6	4.21-14.60	Qal
MW-104•	FT-1	9.24	9.24	3.99-9.24	Qal
MW-105•	PS-2	17.72	17.72	7.47-17.72	Qal
MW-106•	PS-2	12.69	12.69	2.44-12.69	Qal
MW-107•	PS-8	13.0	10.66	5.41-10.66	Qal
MW-108•	PS-8	11.16	11.16	5.91-11.16	Qal
MW-109•	PS-2	15.99	15.99	5.99-15.99	Qal
MW-110•	PS-2	16.27	16.27	6.27-16.27	Qal
MW-111•	PS-8	11.37	11.37	6.37-11.37	Qal
MW-112•	PS-8	15.5	15.5	5.50-15.50	Qal
MW-113•	PS-8	10.94	10.94	5.90-10.94	Qal

a) • indicates Priority 1 site monitoring well.
b) BGL = Below Ground Level.
c) See Figure XX for X-section of hydrogeologic units.

(1) Source: SAIC RI/FS Study, FAFB, 1990.

Appendix G-2
Table 2
Monitoring Well Screen Intervals and
Corresponding Hydrogeologic Units
Fairchild AFB, Washington

Well Number	Site	Total Depth (1)	Screened Interval (1)	Hydrogeologic Unit (2)
MW-120	WW-1	27	16-27	OVB
MW-121	FT-1	22	6-16.3	OVB
MW-122	WW-1	70	54.3-66.3	SBR
MW-123	FT-1	17	7-17	OVB
MW-124	WW-1	55.7	44.7-55.7	SBR
MW-125	WW-1	16	4.5-14.5	OVB
MW-128	SW-1	23	12-22	SBR
MW-129	SW-1	20	10-20	SBR
MW-130	SW-1	23.6	13.6-23.6	SBR
MW-131	SW-1	20	10-20	SBR
MW-132	SW-1	21.8	11.8-21.8	SBR
MW-133	IS-1	25.3	14.5-24.5	SBR
MW-134	SW-1	25.4	15-25	SBR
MW-119	FT-1	204	191-201.75	DBR

MW-118
Note: MW-114 to [redacted], MW-126, MW-127, MW135 to MW-141 located at SW-8 and are not included on this table.

(1) Measured in ft bgs.
(2) OVB indicates well screened in overburden.
SBR indicates well screened in shallow bedrock (<100 ft bgs)
DBR indicates well screened in deep bedrock (>100 ft bgs)

APPENDIX Q:

SURVEY DATA

NOTE: Brass cap elevations represent ground surface
Top of steel casing elevations on flush
mounts represent ground surface

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GROUND COORDINATES OF WELL CASING

BRASS CAP MONUMENT

Monitoring wells 1 thru 35

POINT	NORTHING	EASTING	ELEVATION	
1 101	241, 310.976	2, 790, 610.727	2, 401.160	MW-1
102	241, 456.636	2, 790, 405.497	2, 404.250	MW-2
103	241, 071.703	2, 790, 579.234	2, 400.910	MW-3
104	241, 017.446	2, 790, 328.628	2, 403.030	MW-4
105	242, 102.724	2, 790, 634.705	2, 404.370	MW-5
106	242, 027.497	2, 790, 783.253	2, 404.250	MW-6
107	242, 953.661	2, 790, 478.785	2, 406.050	MW-7
108	242, 935.055	2, 790, 484.670	2, 407.990	MW-8
109	242, 497.565	2, 790, 562.729	2, 407.130	MW-9
110	243, 132.743	2, 790, 807.039	2, 409.660	MW-10
111	242, 513.568	2, 790, 793.286	2, 407.080	MW-11
112	242, 555.534	2, 791, 020.802	2, 404.780	MW-12
113	241, 948.346	2, 791, 115.265	2, 402.190	MW-13
114	247, 636.633	2, 782, 645.782	2, 435.890	MW-14
115	247, 418.641	2, 782, 740.693	2, 438.470	MW-15
116	247, 419.493	2, 782, 208.372	2, 443.940	MW-16
117	248, 124.703	2, 794, 882.022	2, 398.400	MW-17
118	247, 413.074	2, 795, 359.516	2, 390.240	MW-18
119	248, 476.616	2, 795, 330.944	2, 397.550	MW-19
120	247, 916.066	2, 796, 224.994	2, 389.460	MW-20
121	248, 320.259	2, 796, 191.437	2, 394.620	MW-21
122	246, 585.649	2, 794, 948.946	2, 397.170	MW-22
123	246, 306.913	2, 795, 864.779	2, 382.290	MW-23
124	246, 659.239	2, 796, 271.952	2, 386.370	MW-24
125	241, 898.961	2, 781, 756.065	2, 443.390	MW-25
126	239, 183.372	2, 778, 617.120	2, 465.230	MW-26
27 127	239, 506.473	2, 779, 328.681	2, 459.170	MW-27 28
30 130 D	243, 336.407	2, 795, 747.342	2, 423.590	MW-30 29
31 131 D	243, 379.580	2, 785, 833.262	2, 423.610	MW-31
32 132 D	243, 229.839	2, 795, 840.155	2, 428.870	MW-32
33 133	244, 079.632	2, 787, 082.250	2, 425.040	MW-33
34 134	244, 376.710	2, 786, 886.908	2, 427.310	MW-34
35 135	244, 094.039	2, 786, 632.498	2, 427.270	MW-35
28 140	239, 832.209	2, 777, 232.593	2, 463.290	W2200 MW-28
29 141	239, 030.355	2, 777, 417.331	2, 471.960	W2106.3 MW-29

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BORE HOLE OR MONITOR WELL NUMBER	GROUND COORDINATES NORTHING	EASTING	TOP OF STEEL PROTECTIVE CASING ELEVATION	ADDITIONAL ELEVATION	DESCRIPTION
BW1-BH1	250.717	2,790.578	2,406.29		
BW1-BH2	238.392	2,791.282	2,387.32		
BW1-BH3	235.314	2,776.214	2,442.69		
BW1-BH4	239.369	2,782.126	2,440.68		
BW1-BH5	240.501	2,780.564	2,454.53		
BW1-BH6	239.934	2,780.153	2,451.73		
PS9-BH1	243.481	2,783.908	2,430.77		
PS2-BH1	241.521	2,782.314	2,441.17		
PS2-BH2	241.774	2,782.414	2,440.94		
PS7-BH1	236.737	2,785.717	2,432.27		
PS7-BH2	236.728	2,785.605	2,431.61		
154-BH1	242.168	2,789.279	2,410.43		
SWS-BH1	248.209	2,793.600	2,397.07		
MW-36	235.330	2,776.216	2,445.05	2442.7	Ground
MW-37	242.282	2,789.066	2,413.86	2411.0	Ground
MW-38	241.844	2,788.222	2,417.93	2415.8	Ground
MW-39	250.726	2,790.570	2,402.90	2406.7	Ground
MW-40	244.519	2,782.102	2,438.90	2438.44	Top PVC
MW-41	244.573	2,783.056	2,438.46	2438.25	Top PVC
MW-42	244.574	2,782.206	2,438.57	2438.10	Top PVC
MW-43	243.456	2,784.051	2,431.01	2430.46	Top PVC
MW-44	243.588	2,784.036	2,430.83	2430.43	Top PVC
MW-45	243.492	2,784.124	2,430.94	2430.77	Top PVC
MW-46	244.561	2,782.056	2,438.65	2438.28	Top PVC
MW-47	247.938	2,781.206	2,446.47	2444.37	Ground
MW-48	242.892	2,791.093	2,408.73	2405.6	Ground
MW-49	241.442	2,791.144	2,400.55	2395.6	Ground
MW-50	240.958	2,791.166	2,400.22	2398.0	Ground
MW-51	240.512	2,790.663	2,400.77	2397.8	Ground
MW-52	241.542	2,789.608	2,409.31	2406.4	Ground
MW-53	242.006	2,790.023	2,409.75	2405.4	Ground
MW-54	242.841	2,790.180	2,409.95	2409.77	Top PVC
MW-55	241.656	2,782.583	2,439.74	2439.55	Top PVC
MW-56	241.622	2,782.093	2,442.54	2442.15	Top PVC
MW-57	231.335	2,798.235	2,362.37	2355.5	Ground
MW-58	245.650	2,791.000	2,416.88	2416.69	Top PVC
MW-59	241.458	2,791.143	2,401.20	2398.9	Ground
MW-60	242.911	2,791.092	2,408.24	2405.5	Ground
MW-61	242.025	2,790.023	2,408.63	2406.6	Ground
MW-62	247.946	2,791.217	2,446.47	2444.47	Ground
MW-63	248.519	2,795.198	2,401.04	2398.9	Ground
MW-64	245.020	2,779.713	2,456.89	2454.4	Ground
MW-65	244.933	2,783.313	2,442.05	2439.25	Ground
MW-66	243.219	2,785.925	2,425.92	2423.46	Top PVC
MW-67	243.515	2,785.862	2,428.82	2428.51	Top PVC
MW-68	243.302	2,786.014	2,428.77	2428.47	Ground
MW-69	246.378	2,796.267	2,387.29	2385.8	Ground
MW-70	248.211	2,793.598	2,400.03	2398.9	Ground
MW-71	236.744	2,785.596	2,431.39	2430.82	Top PVC
MW-72	236.744	2,785.713	2,432.30	2431.87	Top PVC
MW-73	236.663	2,785.602	2,431.25	2430.72	Top PVC

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MONITORING WELL LOCATIONS - FAIRCHILD A.F.B. SPOKANE WASHINGTON

WELL #	NORTHINGS	EASTINGS	TOP OF CASING ELEV	TOP OF PVC ELEV	BRASS CAP ELEV	REMARKS
74	248410.14	2796197.59	2398.72		2396.24	CASING ELEV @ NORTH TOP 10" SQUARE PLATE
75	247757.22	2796230.44	2391.53		2389.15	"
76	247209.36	2796248.51	2395.63		2393.79	"
77	246695.45	2796267.28	2388.13		2385.73	"
78	248685.13	2797012.76	2400.96		2399.06	"
79	249254.50	2796978.07	2415.02		2412.90	"
80	249227.18	2796974.22	2415.73		2413.56	"
81	246840.10	2796847.14	2386.90		2384.82	"
82	247285.08	2796926.18	2380.42		2378.73	"
83	247945.57	2797103.72	2393.88		2392.52	"
84	249557.23	2796144.90	2410.18		2408.67	"
85	248619.52	2795879.33	2404.62		2402.13	"
87	239929.27	2780107.97	2453.70		2452.24	CASING ELEV @ OPEN LID OPPOSITE HINGE
88	239727.92	2779299.27	2464.85		2462.54	"
89	240462.23	2779300.09	2471.57		2469.18	"
90	240622.17	2779962.49	2470.55		2468.42	"
91	241901.68	2781770.67	2443.02			CASING ELEV @ NORTH TOP LID
92	241895.69	2781770.36	2442.99			"
93	241764.83	2781566.34	2447.71		2445.70	CASING ELEV @ OPEN LID OPPOSITE HINGE
94	246608.97	2794958.93	2399.46		2397.23	"
95	248478.57	2795302.26	2398.61		2396.72	"
96	247383.10	2795360.90	2392.01		2389.86	"
97	249387.42	2795570.58	2407.65		2405.61	"
98	240511.41	2790680.00	2400.14		2398.07	"
99	242536.17	2791023.12	2406.85		2404.72	"
100	240939.42	2791166.23	2400.36			CASING ELEV @ NORTH TOP LID
101	248703.10	2797023.05	2401.57	2401.55	2399.59	CASING ELEV @ OPEN LID OPPOSITE HINGE
102	242591.67	2790844.42	2407.35			CASING ELEV @ NORTH TOP LID
103	242635.56	2790897.59	2407.17			"
104	240259.31	2789947.09	2402.37	2402.38	2400.28	CASING ELEV @ OPEN LID OPPOSITE HINGE
105	241685.21	2783178.18	2435.37			CASING ELEV @ NORTH TOP LID
106	241933.07	2782930.31	2435.74			"
107	243323.29	2785591.61	2428.60			"
108	243431.23	2785544.90	2427.63			"

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ORING WELL LOCATIONS - FAIRCHILD A.F.B. SPOKANE WASHINGTON

#	NORTHINGS	EASTINGS	TOP OF CASING ELEV	TOP OF PVC ELEV	BRASS CAP ELEV	REMARKS
109	241565.30	2782374.07	2440.86			"
110	241375.51	2782464.69	2440.83		-	"
111	243590.27	2785657.51	2427.44			"
112	243493.30	2786234.65	2427.10			"
113	243768.47	2785969.80	2427.38			"
114	245884.75	2796238.45	2386.71	2386.73	2385.16	CASING ELEV @ OPEN LID OPPOSITE HINGE
115	248966.78	2798824.94	2395.08	2395.04	2392.81	"
116	248992.09	2798821.85	2396.16	2396.06	2393.95	"
117	246124.21	2798345.48	2370.91	2370.94	2368.80	"
118	247313.45	2798295.91	2380.21	2380.15		"
119	240332.63	2793355.43	2388.70	2388.80		"
120	242346.47	2791865.32	2399.14	2399.16	~ 2397	Assume 2' Stickup "
121	239257.81	2791994.62	2388.34	2388.45		"
122	242361.21	2791865.94	2399.28	2399.26	~ 2397	Assume 2' Stickup
123	239854.85	2791969.26	2394.13	2394.24		"
124	240962.41	2791916.32	2397.77	2397.89		"
[illegible]	240979.68	2791914.18	2397.71	2397.78	~ 2395.78	Assume 2' Stickup"
126	249798.27	2798754.65	2402.31	2402.33		"
127	246544.88	2800343.09	2370.96	2370.94	2368.86	"
128	240655.70	2779642.92	2471.25	2471.23		CASING ELEV @ OPEN LID OPPOSITE HINGE
129	240121.59	2779344.39	2470.36	2470.37		"
130	239821.25	2779676.38	2460.40	2459.96		"
131	240362.33	2780296.10	2462.32	2462.29		"
132	240620.56	2779985.88	2470.99	2471.03		"
133	241643.09	2781081.71	2438.79	2438.69		"
134	240958.87	2780614.09	2462.23	2462.24		"
135	247956.41	2797102.52	2394.48	2394.43		"
136	245861.71	2796090.23	2385.43	2385.31	2383.43	BRASS DISC MARKED SW8 MW74
137	248747.02	2798659.28	* 2395.16		# 2392.57	*AT PLUG AT TOP #P.K. AT N SIDE CONC PAD
138	244687.38	2800602.36	2371.62	2371.40	2369.31	BRASS DISC MARKED SW1 MW86
139	247563.59	2800297.63	2370.10	2369.94	2368.00	BRASS DISC MARKED MW1
140	246743.06	2795554.44	2390.03	2389.81		CASING ELEV @ OPEN LID OPPOSITE HINGE
141	250882.63	2797493.15	2403.11	2402.94	2400.54	BRASS DISC MARKED SW8 MW75

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MONITORING WELL LOCATIONS - FAIRCHILD A.F.B. SPOKANE WASHINGTON

WELL #	NORTHINGS	EASTINGS	TOP OF CASING ELEV	BM ELEV	
RW-7	246098.46	2796594.38	2384.57	2380.5	GROUND INSIDE 4" DIA C.M.P.
RW-9	248893.53	2796402.53	2398.15	2404.35	NORTH CENTER 4'X4' OPENING IN CONC APPROX 6" ABOVE SLAB
RW-10	249115.56	2796359.03	2398.68	2404.86	TOP NORTH CENTER OF CONC SLAB @ WELL OPENING
RW-11	249127.99	2795990.77	2404.56	2404.57	TOP NORTH CENTER 12" SQUARE CONC RISER
RW-47	247119.91	2800448.98	* 2371.39	# 2368.72	*ELEV AT PLUG #ELEV AT + AT NORTH SIDE CONC PAD

STATION	H2O ELEV	B.M. ELEV	
S POND	2375.36	2376.91	CHISLED + IN S.E. CORNER 4'2X 5' ROCK AT WEST SIDE POND SPRAYED ORANGE ELEV 8-14-91
W POND	2379.58	2380.70	TOP 2" PIPE AT EAST SIDE POND NEAR INLET ELEV8-14-91

odd

HOLE LOCATIONS - FAIRCHILD A.F.B. SPOKANE WASHINGTON

At Craig Road Landfill

ORE HOLE #	NORTHINGS	EASTINGS	GROUND ELEV	TOP OF PVC ELEV
SW8-BH 17	246525.0	2795117.2	2401.8	
18	246303.0	2795933.8	2381.7	
19	247366.5	2765218.6	2390.3	
20	246812.3	2795323.9	2393.4	
21	246791.7	2795248.8	2395.5	2397.2
22	248236.5	2795573.8	2392.8	
23	248216.3	2795519.0	2393.5	
24	247929.5	2795790.1	2392.7	
25	248381.7	2795546.8	2396.7	
26	248501.4	2795845.1	2399.6	
27	248424.6	2796075.6	2397.0	
28	248257.5	2796097.2	2391.2	
29	247968.0	2796114.8	2393.6	
30	248155.3	2795797.1	2390.9	
31	248102.7	2795749.3	2390.8	2391.8
32	246829.0	2795094.8	2397.0	2397.0
33	246847.2	2795632.8	2387.9	
34	247339.5	2795573.8	2379.7	
35	247150.9	2795641.6	2393.2	2393.0
36	247178.8	2795040.4	2395.3	2395.1
37	248448.1	2795651.7	2398.9	2400.0
38	248308.7	2795695.3	2394.7	2395.5

SW8 BH17 -38

MONITORING WELL LOCATIONS - FAIRCHILD A.F.B. SPOKANE WASHINGTON

WELL #	NORTHINGS	EASTINGS	TOP OF PVC ELEV	TOP OF CASING ELEV	BRASS CAP ELEV	REMARKS
86	240617.12	2780568.54	2459.64	2459.84	2457.59	TOP OF CASING ELEVATIONS ARE ON NORTH SIDE OF FLUSH WELLS, OR OPPOSITE HINGE WITH LID OPEN ON ALL OTHER WELLS
142	243604.93	2791070.52	2412.20	2412.33	2410.34	ALL P.V.C. ELEVATIONS ARE ON TOP OF PIPE FACING POINT WHERE CASING ELEVATIONS ARE
143	243288.24	2790994.79	2411.02	2411.10	2409.02	
144	242394.98	2791094.48	2405.43	2405.50	2403.35	
145	242212.32	2791097.03	2405.68	2405.88	2402.96	
146	242920.21	2791349.91	2403.24	2403.27	2400.97	
147	242621.43	2791503.19	2405.98	2406.14	2403.85	
148	241571.06	2790446.70	2406.68	2406.97	2404.31	
149	241566.82	2790644.17	2406.72	2406.87	2404.44	
150	241530.79	2790688.64	2406.54	2406.78	2404.51	
151	241182.58	2790803.32	2400.17	2400.45	2398.20	
152	241133.21	2790720.02	2401.66	2402.23	2399.53	
153	240929.61	2790868.00	2401.87	2402.21	2399.63	
154	240908.66	2790891.67	2401.36	2401.52	2399.16	
155	240935.61	2790680.97	2401.86	2402.37	2399.3[illegible]	
156	241107.71	2790446.31	2405.13	2405.35	2402.83	
157	240666.37	2790669.33	2401.44	2401.71	2398.88	
158	240671.34	2790696.44	2400.50	2401.02	2398.73	
159	240690.62	2790684.39	2400.85	2401.32	2398.89	
160	240647.47	2790652.37	2401.55	2401.57	2399.21	
161	240660.70	2790716.36	2400.74	2400.84	2398.56	
162	240607.13	2790823.27	2401.34	2401.49	2399.08	MW 162 & 163 ARE IN SAME CASING
163	240607.13	2790823.27	2401.38	2401.49	2399.08	
164	241060.58	2780612.07	2462.75	2462.91	2460.71	
165	240725.17	2781058.73	2451.30	2451.33	2449.28	
166	239961.82	2780975.66	2446.35	2446.69	NA	FLUSH MOUNT
167	240619.31	2780007.14	2471.07	2471.31	2468.90	

SW-1
SW1 PS2
WW1 PSZ

MW-1
FT-1

Overtime 2K48.0403

MONITORING WELL LOCATIONS - FAIRCHILD A.F.B. SPOKANE WASHINGTON

WELL #	NORTHINGS	EASTINGS	TOP OF PVC ELEV	TOP OF CASING ELEV	BRASS CAP ELEV	REMARKS
168	240345.22	2780277.28	2462.50	2463.25	2460.53	TOP OF CASING ELEVATIONS ARE ON NORTH SIDE OF FLUSH WELLS, OR OPPOSITE HINGE WITH LID
169	240639.32	2780583.34	2459.67	2459.89	2457.84	OPEN ON ALL OTHER WELLS ALL P.V.C. ELEVATIONS ARE ON TOP OF PIPE
170	240618.32	2780587.70	2459.43	2459.79	2457.53	FACING POINT WHERE CASING ELEVATIONS ARE
171	240625.29	2780641.23	2457.76	2457.77	2455.80	
172	240621.01	2780713.04	2454.71	2455.27	2452.90	MW 172 & 173 ARE IN SAME CASING WELLS NOT MARKED AT TIME OF SURVEY AND PVC ELEVATION
173	240621.01	2780713.04	2454.81	2455.27	2452.90	MAY NOT FIT WELL
174	240690.25	2780585.32	2461.46	2461.68	2459.16	MW 174 & 175 ARE IN SAME CASING
175	240690.25	2780585.32	2461.46	2461.68	2459.16	
176	241736.03	2782795.27	2439.09	2439.28	NA	FLUSH MOUNTS
177	241340.47	2782232.73	2440.70	2440.89	NA	
178	241337.63	2782233.45	2440.61	2440.88	NA	
179	241573.50	2782388.24	2440.59	2440.77	NA	
180	241667.61	2782688.98	2439.20	2439.47	NA	
181	243069.06	2785263.12	2428.33	2428.52	NA	
182	243700.96	2786143.55	2428.09	2428.41	NA	
183	243576.92	2786484.14	2426.60	2426.94	NA	
184	243321.57	2786312.46	2427.27	2427.47	NA	
185	243354.36	2785248.64	2428.78	2429.13	NA	
186	243097.40	2785594.66	2429.35	2429.66	NA	
187	243383.59	2785840.96	2428.48	2428.26	NA	
188	244014.09	2786770.97	2425.22	2425.43	NA	
189	244238.25	2787049.73	2425.88	2426.29	NA	
190	244230.03	2787043.50	2425.83	2426.04	NA	

-SURVEY DATA

WL #	TPVC EL	TOC EL
01	2401.55	2401.57
04	2402.38	2402.37
28	2471.23	2471.25
29	2470.37	2470.36
30	2459.96	2460.40
31	2462.29	2462.32
32	2471.03	2470.99
33	2438.69	2438.79
34	2462.24	2462.23